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A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

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New England Water Works Association
ORGANIZED 1882.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

PUMPING STATION PRACTICE.*

BY F. W. DEAN.†

[*Read February 8, 1928.*]

BOILERS.

There has been for a century a competitive spirit among the managers of pumping stations concerning the so-called "duty" of pumping engines. The earliest case of this was probably in England, and especially in Cornwall, where pumping engines were used for draining mines. This is a district near the Welsh coal fields, where coal was always cheap, but nevertheless the effort to save coal was constantly made. The Cornish engine was developed there, and it was a great advance over earlier types. It violated various principles of heat economy, as is now well understood, but it persisted beyond the middle of the last century, the last prominent case of its installation in this country being at the Pettaconsett Pumping Station of the Providence, R. I., Water Works.

The part that the boiler played in this competition was not so well understood in the early days as it is now. This was due to the fact that combustion is a chemical process and means of determining the perfection of the process had not been developed. It is now known to many that there is a great difference between the efficiencies of boilers when differently fired. The term "efficiency" is now-a-days used instead of "evaporation per pound of fuel from and at 212° F."; it is more scientific.

The efficiency of a boiler is the proportion of the heat which would be derived from complete combustion of the fuel under ideal conditions that enters the water and steam in an actual case. The majority of boilers are probably giving an efficiency of from 50 per cent. to 70 per cent., while within a few years this has been increased to more than 90 per cent. These very high efficiencies come not only from excellent combustion, but from the utilization of as much of the heat as practicable that escapes from the boiler towards the chimney. This heat is not only utilized for heating feed water, but also for heating the air for combustion. Some advantage comes also from reducing the heat lost by radiation, although this is a comparatively small amount.

*A discussion of Chapter XV of *Water-Works Practice*, a manual issued by the American Water Works Association.

†Consulting Engineer, Boston, Mass.

Economy of fuel is given great consideration in pumping plants at the present time, but in most of them it would not pay to go to extremes in the installation of means of economy. It is a duty, however, which everyone should feel, to economize fuel, and financial economy should not always be the end sought. The draft upon the fuel resources of the world is enormous, and they should be conserved as much as practicable.

Most pumping engines are driven by steam and the boiler, therefore, is a necessary part of the plant. There are many incorrect ideas concerning them, but in a general way it can be stated that a boiler is a device for extracting heat from hot gases. There are, therefore, two principal things to be done, one being to burn the fuel so as to produce the maximum quantity of heat, and the other to use a boiler that will most completely absorb the heat produced.

It is evident that there may be many forms which the boiler may take, but it should be remembered that the circulation of the hot gases thoroughly throughout the heating surfaces, and the possibility of keeping the surfaces clean are the most important.

There are two general classes of boilers, namely, fire-tube and water-tube boilers. The former has the water contained in a metal shell through which tubes pass, and through these the hot gases proceed to the chimney. In the water-tube type there are also many small tubes connected at each end to so-called headers or to drums. These parts contain water, and the hot gases pass around the tubes and to some extent come into contact with the headers and drums and give up their heat to them.

While it is not difficult to make the hot gases pass through the tubes of fire-tube boilers, since there is no other place for their passage, it is difficult to make them circulate around the tubes of a water-tube boiler. In fact it cannot be thoroughly done and much of the surface of a water-tube boiler is never reached by the hot gases. The gas circulation is directed by fire-resistant tiles placed, after much experimentation, in the most advantageous positions. As gases, however, take the paths of least resistance, and as near straight lines as possible, they omit in their travel, as before stated, contact with a considerable part of the surface.

Fire-tube boilers are made in various ways, the most usual form in this country being the horizontal return tubular boiler which consists of a horizontal shell with tubes running from one head to the other. It is set in brickwork and the fire is underneath. It possesses several good features. It is low in cost and is a boiler of maximum efficiency. All of the tubes pass about the same amount of gas because the distance from the end of the grate to the up-take is the same through any tube, and for this reason the resistance to the passage of gas through all tubes is the same. It is commonly asserted that the upper tubes pass more gas than others, but if an accurate determination were made it would probably be found that the difference is small.

The heating surfaces of the tubes can be thoroughly cleaned by blowing

and scraping and the efficiency can be maintained. The water surfaces of the tubes cannot be kept clean so well, but various means can be used to clean them. In water-tube boilers the reverse is true. The interior of the tubes, which are in contact with water, can be quite successfully bored out by machines for the purpose, but the fire sides of the tubes cannot be cleaned with any degree of thoroughness. It is done by steam jets, and those parts of the tubes that are directly struck by the jets are well cleaned; the remainder is not. The dirt increases in straight-tube boilers from one side of the boiler to the other, but in bent-tube boilers modern tube blowers are run across and are much more effective than hand blowers. It should be said, however, that modern blowers do some good with straight tubes.

Horizontal Return Tubular Boilers. There is much erroneous information promulgated with reference to horizontal return tubular boilers. It is commonly asserted that they contain more water in proportion to the heating surface than do water-tube boilers. The opposite, however, is the truth, as anybody can ascertain by computing the water contents of examples of each type. There is no harm, however, in having a large water content, as after the water is once heated to the temperature of the steam any further addition of heat does nothing but make steam, and does not have to raise the temperature of the water. The heat required to raise the extra water to the maximum temperature is comparatively small.

It is also commonly asserted that the horizontal return tubular boiler cannot be forced, and that the water circulation is poor. In order to force it, it is merely necessary to burn more fuel as in other boilers, and the output of steam increases. In regard to the circulation this takes care of itself, and it cannot be stopped. It may be slow because there are so many spaces in which it can occur. Water-tube boilers circulate the water rapidly through the tubes nearest the hottest gases because the areas are small, and being in tubes its velocity can be measured by suitable apparatus. This probably cannot be done in horizontal return tubular boilers. Horizontal return tubular boilers are in many cases forced daily, 24 hours per day, from 200 to 300 per cent. of rating and more.

Another superior feature of horizontal return tubular boilers is the small draft loss, which is about two-thirds that of some types of water-tube boilers. For this reason less chimney capacity is required than for others, and there is less difficulty in forcing them.

If high ratings are required, it is advisable to weld the tubes into the back head after they are expanded and beaded in order to prevent leakage. In such cases it is not uncommon to weld the circular seams on the lower half after they are caulked. The back-head seam for some reason does not need welding.

The limitations of horizontal return tubular boilers are in size and pressure. The largest practicable size is about 100 in.; it is said that they have been built as large as 120 in., and 96-in. and 108-in. boilers have been made. Many 90-in. boilers having 260 3-in. tubes 20 ft. long with 4 027

sq. ft. of heating surface are in use, some of them being operated at 300 per cent. of rating. Boilers 102 in. in diameter can be made for 200 lb. pressure and with 5 000 sq. ft. of heating surface giving a rating of 500 h.p.

The old way of making horizontal return tubular boilers with three courses is being abandoned and replaced by two courses in order to reduce the number of joints exposed to the fire. Plates can now be obtained over 15 ft. wide, and there are bending rolls much wider than this. Plates 2 in. thick have been used in marine boilers, but 1 in. may be stated at present as the limit for horizontal return tubular boilers. A study of the theory of the transmission of heat through metal plates shows that increases of thickness make practically no difference in the transmission.

The ordinary design of the means of supporting horizontal return tubular boilers is defective, and should give way to the three-point method, as this is the only way to insure that all supporting parts will have the intended stress during the life of the boiler.

There is no objection, in order to make the most of horizontal return tubular boilers, to placing the tubes $\frac{3}{4}$ in. apart, and many are so made. Nothing is gained by using a wide center space between the tubes.

The steam nozzle should always be placed in the middle of the boiler in order to draw the steam toward the center from all parts and thus diminish the tendency to drag the water along with the steam and cause priming. A perforated pipe should be placed within $\frac{1}{2}$ in. of the top of the boiler, the area of each branch of which should equal half the area of the nozzle. The perforated pipe should be as long as the boiler, or as near that as practicable, and the holes should be $\frac{1}{2}$ in. in diameter along the length of the pipe. The total area of all of the holes should be not over that of the nozzle. The manhole should be strongly reinforced as this is a weak part of a boiler. Rivet holes should always be drilled in the solid plate without preliminary punching, with the plates in place, as thereby the holes necessarily match and the plates are not injured by punching.

The longitudinal joints of boilers are now always butted, and this has converted horizontal return tubular boilers from dangerous to safe boilers, until now there is no safer boiler. The rivets should be driven by a hydraulic machine which derives its power from an accumulator.

Most boilers are provided with too large steam pipes. These pipes are loafing places for the steam, and the smaller ones are cheaper, are more easily bent, permit expansion and contraction with less strain of joints, require smaller valves, less covering, and radiate less heat. It is found by trial that there is practically no loss in pressure by the smaller sizes. The sizes of nozzles and steam pipes should be as follows:

For 60-in. boilers	3 in.
For 72-in. boilers	4 in.
For 84-in. boilers	5 in.
For 90-in. boilers	6 in.
For larger boilers	7 in.

Setting of Horizontal Return Tubular Boilers. It has been the custom to build settings with air spaces, having fire brick inner walls and red brick outer walls. These spaces are likely to cause leakage of air into the furnace, cool the gas, and do not promote combustion to any important extent, and are not controllable. They reduce the stability of the setting and introduce weak connections between the red and fire brick walls. These settings should be built with solid fire brick of the same size, using high grade brick next to the fire and low grade elsewhere, in order that the high grade can be accurately bonded with the low grade. The low grade brick costs some $18 less per thousand than does the high grade, and about the same more than red bricks. The difference in price of the fire brick over the red will be saved in the diminished labor of cutting and fitting, with a far better piece of work. The side and center walls should not be built solid with the front and back walls, but should have expansion spaces where they meet those walls. These spaces should be secured by building in $\frac{1}{8}$-in. boards so as to make it certain that the expansion spaces are really provided. The boards burn out and leave the spaces. If any of these spaces are carried through to the outside walls the outside boards should be removed and the spaces filled with asbestos fibre tightly driven in a few inches.

The covering of the back combustion chamber, which has given so much trouble heretofore, should be of suspended brick arches which are made by several companies. It is common to make the horizontal depth of the combustion chambers two feet, but it is better to make it, in the larger boilers, at least three feet as it may allow the gases to change their direction of flow with lower velocity and diminished resistance.

The smoke box in the larger boilers should be deeper than has been the custom, and the width of the uptake should be greater than the width occupied by the tubes in order to give the side tubes unrestricted exit. The object of the greater depth of the smoke box is to give more space for the gases to turn and to make it more certain that the vacuum in the smoke box will be the same in all parts.

The side walls of the setting should not touch the shell by $\frac{3}{4}$ in., and this space should be filled by asbestos rope tightly caulked in. The non-conducting covering which is afterwards applied is placed in contact with the rope and aids in securing it.

It is the tendency at present to set boilers at considerable height above the grate on the assumption that it promotes economy. This is a mistaken idea, as anyone who is familiar with Scotch boilers must know. Aside from the boiler itself the economy depends upon the perfection of the combustion, or chemically speaking, upon burning the carbon to CO_2 with no CO. The Scotch boiler is one of the most economical types. It has but small firebox volume, and small volume beyond the firebox, and all of the surfaces within which combustion occurs are near the fire and are comparatively cool as they have water on the other side. It thus violates all of the theories which are commonly held. Scotch boilers at sea are always operated by

hot air which is heated by the escaping gas in the uptake, on the Howden System. This promotes combustion.

The reason for the existence of these errors is that the impression prevails that combustion cannot occur without very high temperatures, but it occurs in Scotch boilers as perfectly as in any, notwithstanding the small furnace and combustion volumes and the lowest furnace temperature of any boiler. In other words the lowest furnace temperature that is likely to occur is sufficient to effect the desired combination of oxygen and carbon and produce high CO_2 and no CO.

A large furnace does not compel all of the oxygen to meet all of the combustible gas because there is so much space in which they can [illegible] each other. In the Scotch boiler the space above the fuel is so small that it is impossible for these two gases to fail to come in contact and combine. In a low-set horizontal return tubular boiler, for the same reason as in the Scotch, the two gases are far more likely to meet than would be the case with the high furnace. In a high furnace it is desirable to use a very high bridge wall in order to have a restricted area to compel intimate association of oxygen and carbon.

In hand-fired boilers the air for combustion should be supplied by the grate, by openings in the fire door, and in controllable quantities at the bridge wall. If the two former give sufficient air the air should not be allowed to enter through the bridge wall, or if the air through the grate and bridge wall give sufficient it should not be allowed to pass through the door. In Scotch boilers air is admitted through the door, and when the Howden System is used this air is hot.

The Scotch and other boilers with round furnaces are very free from smoke, and this shows good mixture of gases. In the Scotch boiler tested by the Emergency Fleet Corporation* the gas was converted to 15 per cent. CO_2 in a travel of from 2 ft. to 4 ft. from the back of the bridge wall, and the combustible gas was reduced to zero. In hand firing with coal the efficiency reached 80 per cent. and with oil 84.5 per cent.

Air-Cooled Boiler Settings. There are now on the market several so-called air-cooled boiler settings which are most excellent and prolong the life of settings to an important extent. They consist of an inner wall about 8 in. thick of fire-resisting tiles on the sides and the back, an air space about 8 in. wide outside of this, and an outer wall of red brick or steel plate lined with fire-resisting material. In a hand-fired boiler the air for combustion is supplied to these spaces by openings in the upper part of the back ends of the sides, and in the top of the back end, and it is drawn into the ash pit on each side through openings in the walls below the grate. In the case of stokers it is drawn through the air spaces by a fan and forced to the air boxes of the stokers. In the case of pulverized coal the hot air is blown into the pulverizer or into the burner, or both. The hot air which enters the pulverizer dries the coal to some extent and aids combustion. In this way

*See Bulletin 214, Dept. of the Interior, pp. 272–273.

the furnace walls are kept cool, which prolongs their lives, and the heat which is extracted from them is returned to the fire. The hot air aids combustion and shortens the flame. The air which is drawn through the setting can be previously heated by the escaping gases and yet keep the brickwork sufficiently cool to prevent damage.

Grates. It is common to use shaking grates, and if they are not shaken too much they are good things. Some of them have too little air space, and the air openings are often too narrow. Ample opportunity for air to pass through the grate should be given, but it should be remembered that it is easy to permit too much to pass through. This can be judged from the readings of a CO_2 indicator, which should be in every plant. With a CO_2 indicator stationary grates are as good as shaking grates, but of course require more labor by the fireman.

Mechanical Stokers. Most pumping stations are too small to justify mechanical stokers. They are capable of giving economical service, but they, like ordinary grates, are capable of admitting too much or too little air, and the air cannot be controlled except by the condition of the fire. With western coal their ability to be smokeless may be sufficient justification for using them.

Pulverized Coal. The most perfect means of burning coal is by pulverization and blowing it into an empty furnace. By its use a boiler can be made to respond to demands for steam much more quickly than by other means, as when the coal supply is increased it burns instantly, and when it is reduced the effect is instantaneous. When the time arrives for stopping the fire the coal is shut off from the pulverizer and the machine is stopped. No coal is required for banking, but if the boiler is required to be started it can be more quickly done than by other methods of burning. The coke in the ash is less than by any other means of firing, and the ash requires removing only once a week or once in two weeks.

On account of the ease and quickness of adjustment of the air to the fuel, and their intimate mixture, better economy can be maintained than by any other means, and the ease of adjusting the amount of coal to the requirements prevents waste. Both the coal and air supply can be automatically regulated by the steam flow if desired.

The air-cooled boiler setting is well adapted to pulverized coal, as the hot air can be used for driving the coal through the pulverizer and thus drying it, and by blowing it into the burner, which aids combustion and shortens the flame.

Pulverization is the best means of burning inferior coal, and little if any is too poor to be burnt in this way. Coal that contains so much sulphur that it cannot be used on hand grates or stokers can be consumed, if pulverized, without difficulty. Likewise very high volatile coal which interferes with stoker performance can be burnt with equal facility. Any kind of coal can be burnt without smoke.

Pulverized coal has passed the experimental stage and nobody should

hesitate to use it on the ground that it has not. Small improvements will constantly be made as in other things. Burners need these slight improvements more than other parts.

The Scotch Boiler. Various comments have already been made concerning this type of boiler, and its standing as an economical boiler has been shown. This is a boiler of the internally fired type, and if made with a water-leg combustion chamber has no brickwork except the bridge wall. It has from one to four circular furnaces, depending upon the size, and has been made up to 18 ft. in diameter for steamships, and is frequently made 17 ft. 6 in. in diameter. The maximum pressure is usually 220 lb. per sq. in. although it could be made for higher pressure. Boilers of this type have been made with plates 2 in. thick.

The furnaces run from the front end of the boiler to a combustion chamber in the back end which extends high enough to cover the ends of the tubes. Above the furnaces there are small tubes, 2 in. to 3 in. in diameter, which pass to the front end where they discharge into a smoke box on top of which rests the connection to the chimney.

Waste-gas super-heaters or air heaters or both may be placed in the uptake, and, at sea, air heaters are always used, but usually in connection with forced draft. Forced draft is not necessarily used, however.

While at sea, water-leg combustion chambers are always used; on land a brick-lined combustion chamber is common and on the whole is the more desirable, considering first cost and absence of staybolts. The economy is not affected by either kind of combustion chamber.

The defect of this type of boiler is that it is large for its heating surface, which can hardly be more than 3 000 sq. ft., and is expensive per sq. ft. As there is no brick setting the cost per h.p. compares favorably with the horizontal return tubular boiler with the setting included.

The boiler is covered with the usual kind of non-conducting material, generally 2 in. thick.

The Vertical Fire-Tube Boiler. This type of boiler is used extensively in the New England States in all situations, and in sizes up to 500 h.p. This size can be built for 250-lb. pressure, and is often forced to more than 300 per cent. of rating. It is not only an efficient evaporator, but it superheats the steam from 15° to 40° F., depending upon the length of tubes exposed to the steam. The steam can be still further superheated by means of the locomotive type of super-heater.

A vertical tube absorbs heat throughout its circumference and is perhaps a better heat absorber than a horizontal tube. Tubes sometimes leak at their lower ends, but this can be prevented by welding them in, as is commonly done on locomotives and other boilers.

Many persons think that there is an inherent lack of economy in such boilers, the argument being that as the tubes are vertical the gases pass out rapidly and do not leave their heat behind them. This is an erroneous view. The truth is that the damper is opened enough to burn the amount

of coal necessary to make the steam needed, and as a result a certain number of cubic feet of gas pass through the tubes in that time. This fixes their velocity, and they can move no faster than they would if they passed through horizontal tubes.

An important thing in connection with this type of boiler is tightness of construction of the smoke box. The smoke box should be the extended shell, or a shell tightly riveted or bolted to the boiler, and the top covers should be designed so that they will be air-tight. If this is attended to, the escaping gases will be hotter than in boilers set in brickwork, and yet with superior economy. This is true of all internally fired boilers, such as the Scotch and locomotive types. Usually vertical boilers are provided with movable covers [illegible] overlapping parts which cause the temperature of the escaping gas to be below that of the steam, on account of leakage of air through the spaces between the covers into the smoke-box. All internally fired boilers with tight smoke boxes expel hotter gas than boilers set in brickwork because there is no opportunity for air to leak in and cool it. This is important where economizers are used, to say nothing of the conservation of chimney draft. Air leakage through brickwork is a source of waste. Very little of it enters where it can assist combustion.

This type of boiler requires less draft than other types because the air passes through the fuel bed at right angles to it and encounters less resistance, and for the reason above stated.

Locomotive-Type Boilers. This type of boiler is one of the best and always gives economical results. It can be made from very small to very large sizes and to carry any pressure, say up to 300 lb.

A brick arch can be used in this boiler such as is used in locomotives. This lengthens the path of the gases, which otherwise would be very short, and enables the air which passes through the fire doors to mix with the combustible gases and produce high CO_2. If the brick arch is not used the chance of there being a good mixture of the gas and air is poor, and with the arch the locomotive type of boiler is probably the most economical of all boilers.

Water-Tube Boilers. Something has already been said about this type of boiler. It has its place beyond the limitations of the fire-tube boiler as it lends itself to large size and high pressure. It is very difficult to have the path of the gases where they will do the most good, and if baffles are near enough together to keep the gases close to the tubes the draft loss will be great.

The water-tube boiler was designed to prevent explosions at a time when they were common with fire-tube boilers. The idea was that if the water was in small tubes there could not be an explosion, and if one should occur it would not be serious. Experience has shown that these expectations were not realized, and when it is considered that these boilers have headers and drums, the latter sometimes being 60 in. in diameter, this is not surprising.

There are several kinds of water-tube boilers. Some have water-space headers made in various ways, one at each end, connected by tubes, and by one or more drums above. These are known as horizontal water-tube boilers. The tubes are always inclined, 15 degrees being considered about right. They are sometimes highest at the back end and sometimes at the front. The headers are usually inclined so as to be at right angles to the tubes, but are sometimes vertical with inclined surfaces to meet the tubes at right angles. In such boilers the drum or drums are usually horizontal, and always should be, in order to give the maximum water surface and steam volume, and to allow the steam nozzle to be at the middle of the drum and the safety valves not far from it. A long perforated "dry pipe" should be connected with the steam nozzle running in both directions.

Another kind of water-tube boiler is known as the cross-drum boiler, and consists of headers connected by inclined tubes. A single drum is used and connected to the top of the lower header, this sometimes being at the front of the boiler and sometimes at the back, although generally at the front. A horizontal row of tubes from the top of the higher header conveys the steam to the center of the drum. A baffle plate of a length somewhat greater than that of the portion of the drum entered by the tubes should be hung from the upper part of the drum in front of the tube exits, with its lower edge dipping into the water. The purpose of this baffle is to prevent the entering steam from ruffling up the water; in marine boilers this is of importance. The steam moves slowly to each end of the drums and passes around the ends of the baffle to the general steam space, above which are the steam and safety-valve nozzles.

This type of boiler furnishes dry steam as was shown by tests of boilers for the Emergency Fleet Corporation, the moisture ranging from 0.75 to 1.02 per cent. when working at 152 to 282 per cent. of land rating. The drum was 42 in. in diameter, the normal water level being at the center, and the throttling calorimeter began dripping water when the water level was 10 in. above the center, or 11 in. below the top. At lower ratings the moisture was as low as 0.30 per cent. These boilers were provided with perforated dry pipes. Boilers of this type carry water better than those with longitudinal drums, because the drum is supplied with steam over its whole length instead of at one end.

The headers of water-tube boilers are made of steel plates, two for each header, connected together in some manner at the edges. The inner of these plates is known as the tube plate and the outer as the hand-hole plate. The tubes are expanded into the tube plate and project through about $\frac{1}{2}$ in., this projection being bell shaped. The plates of the header are usually, but not always, stayed together by screwed staybolts headed over. They often have $\frac{3}{4}$-in. longitudinal holes through which the tubes can be blown, and holes that are not so used are plugged by hollow metal plugs. The holes in the hand-hole plate are closed in various ways.

Water-Tube Boilers with Bent Tubes. These boilers have bent tubes

and drums, but no headers. They are often called vertical water-tube boilers, and have two, three, or four drums, and sometimes more. The tubes enter the drums into which they are expanded and belled. By placing a pair of these boilers in one setting, boilers of enormous size have been made. Tubes 3½ in. in diameter are most commonly used.

The efficiency of boilers of this type depends upon the location and length of the baffles. The object is, of course, to cause the hot gases to follow the tubes. Sometimes a special pair of drums connected by tubes is added, into which the feed water is introduced, thus forming an economizer. In all boilers of this type the feed water is introduced into the last pass which serves as an economizer to some extent. This type of boiler, if the baffles are well placed, is an efficient one.

On account of the resistance of the tubes to the flow of water and the need of a head to cause it to flow from drum to drum, the water level is very variable and rises in the front drum when the power is increased.

Baffles. The baffles in water-tube boilers are means of dividing the spaces among the tubes into passages for the circulation of the hot gases in order that the tubes may be well swept by them and given an opportunity to absorb the heat which they contain.

In horizontal water-tube boilers the baffles are sometimes parallel to the tubes and oftener approximately at right angles to them. In the former case the baffles are simpler and more durable than the others, and more likely to be gas tight in consequence of not having to fit around the tubes. They are also more easily applied and removed. It should be stated, however, that transverse baffles are now often made of concrete and poured in place thus properly fitting around the tubes. They do not crack and fall out and are much more durable than tile baffles. Longitudinal baffles cause the gases to more completely sweep the tubes than do transverse baffles, and through hollow staybolts in the headers the tubes can be better cleaned by steam jets than when transverse baffles are used.

Boilers with transverse baffles cause the gases to move in transverse streams, and as air that enters through the fire doors immediately turns upward, it has little tendency to mix with the combustible gases because it and the gases pursue parallel paths.

In designing horizontal baffles the tendency is to make them too short and thus cause the gases to omit the ends of the tubes and to keep out of the corners near the baffles above. Experiment shows that the gases flow close to the ends of the baffles. Horizontal baffles should be on the lowest row of tubes or no higher than on the second row. When they are higher the tubes above the bottom have little contact with the gases, and none at all near the front ends. Thus some of the heating surface becomes useless. Similarly the highest baffle should be on top of the highest row of tubes instead of under it as it is sometimes. In the latter case the upper row is nearly, if not quite, useless.

The lowest baffle, if horizontal, should be in contact with the front

header, for if not it allows the cold air which enters through the door to pass directly up in contact with the header and does not aid combustion but cools the boiler. This phenomenon always occurs in boilers with transverse baffles whether fired by hand or by stokers.

The more baffles there are in a boiler the more economical it is, but there is an advisable limit in order to avoid too great a draft loss. Many horizontally baffled boilers have only two baffles, one at the top and one at the bottom, but all such boilers, unless they are very small, should have three baffles or more, depending upon the size.

In both types of water-tube boilers the gases make every effort to short circuit, or in other words to avoid passing into corners or parts of the boiler where there is the least obstacle. This is not only proved by draft and temperature measurements, but can be plainly seen by providing inspection holes in the sides of the boilers. Where there is no flame, sparks show the course of the gases.

Circulation in Water-Tube Boilers. Much has been written on this subject. It is important for proper circulation that the water should be freely supplied to the tubes. The water in horizontal water-tube boilers is impeded by the necessity of its turning around sharp corners in entering the tubes from the headers, but it probably is able to do this so that no tubes are deficient in water supply. It is an important principle that of all parts of a water-tube boiler, the tubes themselves should have the least area for water passage: so that their entrance and exit should be unimpeded.

In the header type of boiler the most active circulation is through the lowest row of tubes and moves from the lower to the higher header. In a cross-drum boiler the circulation diminishes in tubes above the lowest until near the middle where it is variable. In tubes above the middle it is in the opposite direction. In horizontal water-tube boilers with longitudinal drums the return circulation may be partly or largely through the drum.

Steel Casings. Boilers are frequently enclosed in steel casings; always in marine work. This is a good thing and aids in keeping the brickwork in good condition. On land it is done to prevent air from leaking through the brickwork, but it does not accomplish it. It is found by placing observation holes in the walls that streams of air can be seen burning in the combustible gases as they enter through interstices in the brickwork. It can be inferred from this that the air enters the brickwork at the bottom of the furnace and flows through it and between it and the casing to all parts of the setting. When it does not encounter combustible gases, or when it enters where the temperature is too low for combustion it is a source of waste. If the steel casing was not used the brickwork would be tightly pointed on the outside and leakage prevented to some extent, but in water-tube boilers it is difficult, if not impossible, to prevent excessive air leakage.

Workmanship. Good workmanship is frequently mentioned, but not so well understood. It is probable that all boiler makers understand how to do good work, but sometimes do not practice it in order to reduce the cost. It consists in part in having the rivet holes drilled with all plates and butt straps in place so that the holes will exactly match, in having the plates in contact before riveting and so close after riveting and before caulking that a steel "feeler" 0.003 in. thick cannot be inserted sufficiently far to touch the rivets. The common method of punching the holes small and reaming them afterwards should be abandoned in favor of drilling from the solid, as punching injures the material. If a boiler-works is equipped with suitable drilling machines the latter method is the cheaper. If staybolts are used they should fill the holes tightly and the heads should be central. If flexible staybolts are used the sockets should be welded to the plates on the outside and not screwed in, as is common, the reason being that the taper of the screw exerts tremendous splitting pressure on the plates, and as staybolts are so near together and the sockets so large the solid plate between them is inadequate to stand the stress.

Tube holes should be as small as possible consistent with passing tubes in and out, in order to prevent excessive enlargement of the tubes when expanded and beaded. If tubes seriously crack inbeading they should be replaced by others.

Tube and rivet holes should be slightly chamfered on both sides of tube plates and where the heads of rivets bear.

Riveting. It has long been established that the cause of the explosions of boiler shells was longitudinal lap joints which have been abandoned for many years. A relic of the lap joint is commonly used, and boiler shells will not be absolutely safe until it is abandoned. The reference is to the butt joints with the inside straps wider than the outside. Part of this joint is a lap joint with its property of causing the plate to bend back and forth with changes of pressure, just as in the lap joint but of diminished amount. Bending back and forth causes the plate to crack, and a number of wide butt strap joints have cracked but fortunately have been discovered before they ruptured. This trouble can be prevented by making the straps of equal widths. If there are three rows of rivets on each side of the center of the joints, the outside row having double the pitch of the inner, the joint efficiency is about 86 per cent. If a greater efficiency is required the use of four or five rows of rivets each side of the center will be necessary. This causes the pitch of the outside rows to be very wide and the use of the saw-tooth form for the outside butt strap is necessary. By this means the edge of the plate is everywhere near the rivets and effective caulking can be done. These two forms of joint are illustrated in the boiler code of the American Society of Mechanical Engineers. Such joints may have a theoretical efficiency of 94 per cent.

The pounding of plates near the edges to bring them close to the plates which they join, should not be permitted, and if it should be done a

"flatter" should be used against the plate to take the blows of the hammer. Usually the fitting of the plates and the closing effect of the riveter brings the plates close together so that caulking can be properly done.

Size of Tubes in Horizontal Return Tubular Boilers. In some parts of the country, especially where high volatile coal is used, tubes 4 in. in diameter are used. East of this region tubes of 3½ in. and 3 in. are used. It is better to use 3-in. tubes because more heating surface can be provided in the boiler, and by their use the boiler can be smaller. It is sometimes stated that it is necessary to use large tubes because small ones fill up with soot. This is true if they are not cleaned, and an advantage of small tubes is that they compel frequent cleaning. They therefore are advantageous besides having the merit of splitting the gases into finer streams and of placing in the boiler more heating surface. Modern tube blowers enable the tubes to be blown quickly and easily.

Good combustion prevents tubes from filling rapidly with soot.

Water Glasses, Gage Cocks and Feed-Water Regulators. It is customary to equip boilers with three gage cocks and one water glass. It is better to have two water glasses because gage cocks are seldom used, and it is important to have two means of observing the height of the water and this is provided by having two glasses. It is also important to have short water glasses in order to prevent the water from being carried too high. Glasses 6 in. long are ample for horizontal boilers of any size.

Feed-water regulators are now so frequently used that they may as well be considered unobjectionable. If of the right kind they keep the water at the correct height, but sluggish action of such devices is objectionable.

Soot Blowers. Soot blowers for boiler tubes render tube blowing easy, and with them there is no reason for using large tubes.

Temperature of Escaping Gases. It has been found by using thermocouples at many points in the same horizontal planes of a boiler uptake and taking simultaneous readings that the temperatures differ greatly. In a certain case the differences were as much as 100° F. In taking temperatures it is generally thought that by placing the bulb of a thermometer in the center of the uptake the most correct results are obtained, but the readings are likely to be, and probably always are, too high. A more accurate and representative means of obtaining the temperature is to use a tube of nitrogen running through the center of the longest dimension of the uptake. This operates by expansion of the nitrogen and will probably be subjected to a fair range of temperatures. This operates upon a mechanism that is graduated to indicate the temperature, and it probably remains correct indefinitely.

Tests of Plates from Old Boilers. There have been a few tests of the plates from horizontal return tubular boilers taken from the part which is subjected to the supposed maximum temperatures. It has been assumed that the plates in such positions would have important defects, but the tests

show that they are as good as new with slightly lower tensile strength, indicating that they have been slightly annealed. From this the conclusion is that the quality of steel plates in boilers subjected to heat is not affected by years of service.

Importance of Keeping Boilers Clean. Most of the troubles of boilers are due to the accumulation of "dirt" and scale. This is likely to result in the bulging of plates, furnaces or tubes of water-tube boilers and sometimes in their rupture. It causes a considerable loss of efficiency. There are various compounds that are used for preventing scale which are effective to a greater or less extent. The determination of which suits the case in hand can be made by a properly qualified chemist and by trial. Care should be taken not to use too much compound as it causes boilers to prime and this results in lifting the water, and if the chemical passes out it causes trouble in engines, turbines, dye houses, or anything in which the steam is used. There is no kind of boiler that is not injured by dirt or scale, both in condition and performance. Other means of preventing scale are sometimes used.

Superheated Steam. Superheated steam is steam that is subjected to heat after it leaves the boiler. The heat dries out the moisture if not excessive and then raises the temperature above that due to its pressure. The superheat may be as high as 300° F. above that due to the pressure.

Moderate superheat is obtained in vertical fire-tube boilers and in other types by utilizing the escaping gases. For higher degrees of superheat the hot gases are used before they have given up the greater part of their heat to the boiler. A type of super-heater is the "radiant-heat superheater" which occupies a part of the furnace walls and is subjected to furnace temperature. Sometimes the radiant super-heater and the other type are both used in one boiler. Super-heaters are used in all locomotives, and in engines and turbines for all purposes.

The effect of the use of superheated steam is to reduce the steam consumption, and therefore that of fuel, to an extent which depends upon the degree of superheat. It is a very important cause of economy.

Boiler Room Instruments. It is impossible for a fireman to know whether he is firing properly unless there are instruments conveniently located so that he can see them. One of the most important is a CO_2 indicator and recorder. This should be checked occasionally by an Orsat apparatus and operated to show CO as well as CO_2. It is important to so fire that CO is not present because it is a cause of great loss of efficiency if present in much quantity. The reason for this is that a pound of carbon burnt to CO yields about 4 450 B.t.u., but if burnt to CO_2 it yields about 14 600 B.t.u.

In firing high CO_2 is desirable, but if it is higher than 13 per cent. with hand firing there is likely to be some CO. With other means of firing CO_2 may be safely carried higher, but if much higher, brickwork will suffer from high temperature, unless the furnace walls are air cooled or lined with water pipes.

It is also important to have a flue-gas thermometer that will indicate and record the temperature. In this case the element, as before stated, which is exposed to the hot gases should pass through the whole width of the uptake and thus give an approximate average indication of the temperature, as it varies greatly in different parts of the uptake. It should not be placed where it is likely to encounter air from leaks in the uptake, and every part of the conduit for escaping gas should be air-tight at least as far as the thermometer unit.

A draft gage is important, and a differential gage that shows the uptake and furnace drafts is advisable. In addition to the above a steam-flow meter for each boiler, some kind of feed-water meter, such as a Venturi or V-notch meter, and a scale for weighing the coal are advisable; of course the latter is always installed.

If superheated steam is used a thermometer for showing the total temperature of the steam is necessary.

Steam soot-blowers are very important, and where they are used the flue temperatue records show what effect blowing has in improving the absorption of heat by the tubes.

Pumping Engines.

As with boilers, there are many types of pumping engines, and there have been many efforts to improve their economy in the use of steam, or whatever power medium is used.

Reciprocating Pumps. After the Cornish engine the flywheel engine became the most economical steam engine, and its economy has improved ever since.

The Morris engine that was installed at the Lowell, Mass. Water Works about 1870 by the Southwark Foundry and Machine Co. of Philadelphia was about the first economical flywheel pumping engine in the country. This was quickly followed by the Leavitt engine at Lynn, Mass., and this was the most economical pumping engine that had ever been built up to that time. Almost immediately two of the same type were installed at Lawrence, Mass., and other Leavitt engines were built from time to time with ever improving economies.

The Morris engine at Lowell and all of the Leavitt engines were vertical. At the present time many large horizontal pumping engines are being built, even up to 20 m.g.d. capacity. It is hardly justifiable to build horizontal engines of capacities above 10 m.g.d. It can only be justified by low first cost, but there are other things to be considered. The horizontal engine has more power consumed by friction than the vertical, and the repairs are heavier.

As the economy improved after 1870 the vertical engine with three steam cylinders, pumps and cranks, was introduced by Edwin Reynolds of Milwaukee, and this has remained the most economical type of steam

pumping engine up to the present time. These engines are of the triple expansion type, with few exceptions.

In the effort to go to extremes in economy of steam in these engines Mr. Reynolds adopted the single-beat poppet valve for the low-pressure cylinder, and for the exhaust valves of the intermediate cylinder. These valves are in the cylinder heads, and when closed the heads are almost as smooth and continuous as if there were no valves. Thus the clearance volumes and surfaces are at irreducible minima, and nearly ideal for the most economical results. Moreover if the valves are tight originally they are likely to remain so indefinitely. The inlet valves open away from the cylinder and the exhaust valves into the cylinder, the piston being away from the head when this occurs.

The valves of the high-pressure cylinder and the inlet valves of the intermediate cylinder are of the Corliss type, but it would be better if they, too, were of the poppet type. It would, however, be desirable to make them double beat in order to balance them for the high pressure of the steam. The clearance volume would be greater for double beat than for the single, but the advantage of their remaining tight, if so originally, renders them superior to the Corliss valve. The latter valve is difficult to make tight in the first place, and as it tends to wear smaller and its seat larger it must begin to leak after some service. Gridiron valves if originally tight remain so indefinitely, but they and their seats have a great deal of surface which promotes condensation of steam.

The pumps of these engines are three in number, and are under the cylinders and below the shaft. The pumps are single acting and each plunger passes through a stuffing box at the top of the pump. The stuffing box may be a source of friction on the plungers if the packing is not of the best kind and carefully adjusted. The weights of the plungers are different and are such that each with the weight of the steam piston and other parts connecting the piston and plunger are the same in order to maintain a uniform rate of revolution of the shaft. The pump plungers are connected to the steam cross-heads by four rods which straddle the shaft.

The suction and discharge valves are small and are usually placed upon so-called cages rather than directly upon the transverse plates of the pumps. This feature for certain reasons reduces the size of the pump chambers and the cost of production.

The bed plates usually rest upon the tops of the pump chambers and thus the amount of masonry for foundations is reduced. A result of this is to make a less congested and better lighted space around the pumps.

As this type of pumping engine has given the best results of any reciprocating engines some examples are given in the following table:

RESULTS OF TESTS OF CERTAIN THREE-CRANK VERTICAL TRIPLE EXPANSION PUMPING ENGINES.

Location.	Louisville.	Buffalo.	Cleveland.	Cleveland.
Date of test	May, 1909.	Apr., 1914.	Oct., 1918.	Oct., 1918.
Diameters of steam cylinders — in.	30–56½–84	34–64–98	36–68–108	32–60–96
Diameters of plungers — in.	33¼	32¼	31.63	34.75
Stroke of pistons and plungers — in.	60	66	66	66
R.P.M., rated	24.019	20	20.61	21.35
Capacity in 24-hr., rated — m.g.*	24	21	20	25
Total head of water — ft.	207.93	297.7	377.2	255.4
Steam gage pressure at engine — lb.	155.15	159.43	207.1	203.8
Superheat at engine — °F.	109.8	105.2	136	114.4
Vacuum — in.	26.88	28.00	28.26	28.43
Average power, steam cylinders — I. h.p.	925.7	1 074.9†	1 417	1 170
Steam per I. h.p. per hr. — lb.	9.64	9.77‡	8.89	9.29
Thermal efficiency, steam cylinders — per cent.	22.25	....	25.60	22.89
Duty per 1 000 lb. steam — m. ft. lb.§	195.02	202.63	211.0	206.2
Friction of engine — per cent.	5.00	....	5.21	3.29

*Million gal. †Pump h.p. ‡Steam per pump h.p. per hr. §Million ft. lb.

An excellent form of horizontal compound flywheel pumping engine is that having the two cylinders as in a cross-compound mill engine and a pump behind each. An objection is that the rear heads of both steam cylinders are pierced for the pump rods and considering this and the fact that there are distance pieces between the steam and pump cylinders it is troublesome to remove the rear heads of the former. If the pump cylinders are not rather far from the steam cylinders, the cold pump rods enter the steam cylinders and cause some condensation.

These features have caused a modification of the type, such that the steam cylinders are at one end of the engine and the pumps at the other. The cross heads, connecting rods and cranks are between the steam and pump cylinders, and one head of each steam and pump cylinder can be removed without any unusual inconvenience.

Pumps of this type with moderate steam pressures without superheat will give a duty of some 137 million ft. lb. of work per 1 000 lb. of dry steam consumed. This can be increased to 150 millions or more by passing the high-pressure exhaust through a reheater heated by the escaping boiler gases. The moisture in this steam is not only evaporated but the steam is likely to be superheated some 50° F. by this means.

Direct-Acting Pumps. Direct-acting pumps without flywheels of various sizes up to those of 10-m.g.d. capacity have been popular on account of their low cost and reliability. They are usually duplex, that is to say there are two pumps complete side by side, and the valves of each side are operated by the other side. The effect of the connection of the two sides through their valve gears as always built is such that the stroke of one begins before the other ends. This to some extent keeps the flow of the water continuous and thereby diminishes the impact of the water on the system. These pumps when of much size were compound on each side,

thus having two high-pressure and two low-pressure cylinders, and sometimes they were triple expansion, thus having six steam cylinders.

In this kind of pumping engine the steam lines of the indicator diagrams from each steam cylinder are nearly horizontal and straight, and the expansion of the steam is small and comes only from the steam of one cylinder entering a larger one. The duty of such an engine would sometimes reach 60 million ft. lb. per 1 000 lb. of unsuperheated steam. The triple expansion type was of course more economical.

It was natural that efforts should be made to improve the type so that the steam could be cut off in the high-pressure cylinder and get true expansion as in a flywheel engine. In the direct engine as built for many years, if the steam was cut off and expanded, the pressure would fall so low that the stroke would not be completed. In the flywheel engine the stroke is completed by the inertia of the flywheel which gives out energy that is stored in the first part of the stroke. In order to make the direct-acting engine capable of having the steam supply cut off at some point in the stroke of the high-pressure piston it was necessary to have a mechanism attached that would imitate the flywheel in absorbing energy from the steam when it was at high pressure in the early part of the stroke and give it out at the latter part when the steam had expanded to low pressure, and thus complete the stroke. Such mechanism was developed and operated with success, and was inferior to the flywheel-effect only in respect to compression at the end of the stroke, which was always lacking. The mechanism consisted for each side of the engine of a pair of oscillating cylinders with plungers acting upon water. The plungers were forced in during the first half of the stroke and the discharged water raised an accumulator weight. After the middle of the stroke the accumulator forced back the water into the oscillating cylinder, the plungers of which completed the stroke of the engine. These engines were built both horizontal and vertical and compound and triple expansion, but they were not in general favor.

Another ingenious application to the duplex direct-acting pump for producing the flywheel effect was known as the d'Auria engine. Between the steam and water cylinders of each half of the engine and in line with them, there is a cylinder containing a piston which circulates water through a closed pipe connecting the ends of this cylinder. The area of this piston and the diameter and length of the circulation pipe are such that the water, by its acceleration at the early part of the stroke, will absorb energy from the steam and give it out at the latter part. This enables the steam to be cut off early in the stroke, worked expansively, and the stroke to be completed. The device was effective and in one case, with steam at 152 lb. superheated 179° F., water pressure 104 lb. and 5-m.g.d. capacity, the engine gave a duty of 140 million ft. lb. and used 12.7 lb. of steam per indicated h.p. per hour. The friction of the engine was 7.15 per cent. This engine is not now made, but it and the Worthington economical direct-acting engine are here described as matters of interest and record.

Centrifugal Pumps. Within a comparatively few years a great deal of study has been given to centrifugal pumps, with the object of increasing their mechanical efficiency and doing away with end thrust. The simplicity of the centrifugal pump is attractive, and by these studies there has been a great advance in the mechanical efficiency, which now may be as high as 84 per cent. and even more. By this is meant that the power delivered to the water at the discharge end of the pump is this percentage of the driving power. It thus becomes in mechanical efficiency a closer rival than formerly of the piston and plunger pump. In order therefore to render this pump economical it is merely necessary to drive it by an economical prime mover. The low cost of a centrifugal plant is such that the fixed charges are low, and as the attendance and a few other costs are as low as, or lower than, those of a piston and plunger pump, they are being used in greater numbers.

Centrifugal pump casings should be made in halves, the division being through the shaft center. By this means the interior can be accurately machined and carefully finished, and this in connection with an accurately machined and carefully finished impeller is necessary for high efficiency. Moreover this construction renders it possible to inspect the interior.

Centrifugal pumps are made to operate against any pressure by having a number of pumps in series, each taking water from the preceding and the last delivering the water to the discharge pipe. These different pumps are called stages and the casings for each longitudinal half are usually in one casting on the same shaft.

The impellers should be of bronze and the shaft should be covered with bronze sleeves to prevent corrosion with consequent loss of efficiency.

While the efficiency of centrifugal pumps, as mentioned above, can be realized it should be remembered that there are some things still to be learned about them, the theory being still uncertain. It should also be remembered that the efficiency rapidly falls off as departures are made from the rated capacity. On this account the cost of pumping by centrifugal pumps is very variable, and more so than with piston and plunger pumps.

Means of Driving Centrifugal Pumps. Centrifugal pumps may be driven by reciprocating steam engines, steam turbines, Diesel engines or electric motors. Of the reciprocating engines, simple or compound engines of well-known counterflow types, this type being the common engine in which the steam is admitted and exhausted at the ends of the cylinders, may be used. The Uniflow engine may be used with great convenience and simplicity, and with an economy equal to that of a compound or triple expansion engine.

The Uniflow engine has one cylinder and is so designed that the steam is admitted at each end and exhausted in the middle. It should be remembered that the economy of a steam engine is derived from small cylinder loss of heat and condensation and considerable expansion. In the counter-

flow engine, ignoring superheat, expansion through two or more cylinders is the means of doing this, but in the Uniflow engine the method of admitting and exhausting the steam accomplishes it, especially if the cylinder heads are steam jacketed, which in counterflow engines, is of little or no advantage. The physical reasons for the economy of the Uniflow engine are that the steam is not exhausted through the inlet ports and does not, therefore, carry heat away from them, and as it moves directly away from the heads instead of sweeping over them it does not carry much heat away from them. The theory is that with a given expansion of steam in a Uniflow cylinder the economy will be the same as that of a multi-expansion engine of the counterflow type with the same expansion. An important feature of the Uniflow engine is that the economy with different expansions does not differ as much as in counterflow engines. In other words the efficiency curve of a Uniflow is flatter than that of a multi-expansion engine, and this renders it advantageous for variable loads.

To illustrate the economy of a Uniflow engine having a small cylinder only 23 in. by 30 in., and the small variation in the economy with different loads, the following results obtained by the writer are given. The steam used was condensed in a tight surface condenser and weighed on tested scales.

CONDENSING UNIFLOW ENGINE.

Steam consumptions per indicated h.p. per hour, at 120 revolutions per minute.

Approximate relative loads.	¼	½	¾	Full.
Actual powers with dry steam — I h.p.	73.01	136.53	222.45	283.26
and steam consumptions — lb.	12.74	12.55	13.38	14.24
Actual powers with 55° to 60° — I h.p.	79.26	163.26	232.00	313.62
superheat, and steam consumptions — lb.	11.33	11.59	12.32	12.99
Actual powers with 107° to 112° — I h.p.	74.75	151.96	217.41	295.72
superheat, and steam consumptions — lb.	11.67	11.82	12.10	12.30
Actual powers with 154° to 164° — I h.p.	92.37	175.35	238.23	333.15
superheat, and steam consumptions — lb	9.25	10.06	10.72	11.22

Steam pressure about 165 lb. Vacuum, 23.78 in. to 24.95 in. The vacuums were very low on account of too small a condenser.

Diesel engines, which use oil as fuel directly in the cylinders, can be used advantageously in some parts of the country on account of their low fuel consumption, this being due to their high thermal efficiency. There are parts of the country, however, where the price of oil is sufficiently high and that of coal sufficiently low to nullify the effect of the economy of the Diesel engine. The steam-driven pump is more desirable from an economical standpoint, especially if the pumping station is already provided with boilers. Diesel engines are expensive, require a good deal of room and expensive foundations. They are complicated, and not only have a number of cylinders, but an air compressor and starting tank to contain air of high

pressure. The cost of maintenance is usually high, although there are places where it appears not to be excessively so. The fixed charges are high on account of the high first cost.

In small plants gasoline engines may be advisable, but a special study of each case should be made.

Electric motors are often used to drive centrifugal pumps, the source of the power often being public service stations. In general electrically-driven pumps are small, but of course there is no reason why they may not be large. A great deal of consideration should be given to the safety of the electrical supply lines, and lines in duplicate are desirable; if underground, so much the better.

The question of the cost of electric current is ever arising, but no matter what the cost there are cases where electricity is not advisable from an economical standpoint. If the pumping station has a steam plant with steam pumping engines and a personnel adequate to operate it, and if it has to be operated all of the time, or if not all the time, occasionally and at any time, it is folly to buy electricity. The cost of power is made up of the fixed charges of all kinds of the plant, the cost of fuel, supplies and labor, and if these are compared with and without purchased electricity it will be found that such electricity is not advisable. If electricity must be used it will be found, considering all of the fixed and other charges, that it should be made at the plant. In regard to the particular kind of motor to be used, it is best to consult an electrical engineer.

If the head to which a centrifugal pump should work is beyond its capacity it merely whirls the water in the casing, and if it is able to pump the water against the required head and the discharge pipe valve is closed it continues to whirl the water, and the pressure corresponding to the maximum head to which it will work is exerted upon the casing.

If buying a centrifugal pump for the main supply, it is best to have the builder furnish an efficiency curve in order that it can be seen what is likely to occur in meeting the demands for water.

Steam turbines can be successfully used for driving centrifugal pumps, but usually with reduction gears. Such gears are unobjectionable and have a very high efficiency so that their friction does not materially affect the general efficiency of the pump assembly. Steam turbines are more economical, when of much power, than any kind of piston engine that might be used, but their economy is dependent upon a high vacuum, say 28 in., and the condensing apparatus is frequently not operated and maintained so that the high vacuum is realized. The Uniflow engine, however, will give remarkable economy even with a vacuum as low as 23 in., and if it is 28 in. the economy is correspondingly better.

Condensers.

Of the two kinds of condensers, jet and surface, there is an important advantage in the latter, namely, that the steam consumption of the engine can be determined with the greatest accuracy and in short tests. It is simply necessary to weigh the condensed steam as it is discharged by the air pump, and if the engine is doing constant work the duration may be as short as one hour. The weight of the condensed steam can be determined every ten minutes, and if these weights substantially agree there is no reason for continuing the test.

On the other hand, if a test is made by weighing the water pumped into the boiler the test must be eight hours or more long, because the water level in the boiler is constantly varying with the result that it cannot be said that the final water level is the same as the initial. The water surfaces in boilers are always large and a small variation in the level gives a considerable error in the quantity of water. Moreover, steam for any purpose can be taken from the boiler without causing an error in the steam condensed from the main engine.

Surface condensers are made of circular, rectangular or triangular cross-section, but the latter are generally preferred from considerations of efficiency. When a high vacuum is desired special apparatus is required for removing the ultimate air.

In writing specifications it is best to determine the size of tube desired and require all competitors to base their estimates upon it. With this and a requirement of the vacuum desired, comparison of prices can be more intelligently made.

Surface condensers in dirty water districts cause some trouble, but on the whole are preferable.

Tight Steam Engine Valves. In writing specifications of pumping or auxiliary engines, it should be required that inlet steam and exhaust valves should be made tight with a full head of steam. It should not be assumed that they will make themselves so by wear. This is preferably done in the construction shop rather than after the engine is erected in the place of use. Leaky valves are a prolific source of waste of steam and of reduction of duty. Corliss valves are now regarded as less desirable on this account than poppet valves, and every high-duty engine should have the latter.

IODINE IN THE PUBLIC WATER SUPPLIES OF MASSACHUSETTS.

BY H. W. CLARK.*

[*Received March 28, 1928.*]

There are in Massachusetts two hundred and nineteen cities and towns with public water supplies and these supplies, about equally divided in number between ground and surface waters, are available to 96 per cent. of the population of the state.† Although the number of these supplies is about equally divided between ground and surface waters, the latter are of much the greater volume and importance and are used by about 85 per cent. of the population. The Metropolitan District, for instance, consisting of Boston and nineteen surrounding cities and towns having a population of more than 1 500 000, uses surface water. These surface supplies are largely from natural lakes or from reservoirs constructed to receive and store for a considerable period the water of brooks and other streams. There is only one city in the state that takes water directly from a river without storage, and this water is filtered. The ground waters of the state are largely taken from driven tubular wells, 25 to 50 ft. in depth, with a few supplies taken from large curb wells. Wells of some municipalities are in close proximity to rivers and receive much river water after filtration through the ground.

During 1925 and 1926 the Massachusetts Department of Public Health determined the amount of iodine in certain of the supplies of the state. It was impossible to determine iodine in all of the public supplies during those two years, but enough were examined to give a good cross-section of the water supplies of the state and hence a fairly correct idea of the variation in iodine content of different ground and surface waters. Up to date, 97 supplies have been examined for iodine, namely, 62 surface and 35 ground water supplies. Besides these, a number of samples of river water, rain water and fish have been examined for iodine. In the course of this work it has been found that not only do the waters of the state differ greatly in their iodine content but that certain supplies vary materially at different seasons of the year, less iodine being present in winter and spring when melting snows and rain are filling ponds and reservoirs than in summer or dry periods when these supplies are low, little water is coming to them and they are also being concentrated by evaporation. The great difference in iodine content in different supplies, often noticeable even in the supplies of adjacent municipalities, is due to the great variation in the character of the soils and rocks of the state.

*Chief Chemist, Massachusetts Department of Public Health.

† 4 144 205 Census 1925.

PLATE I.
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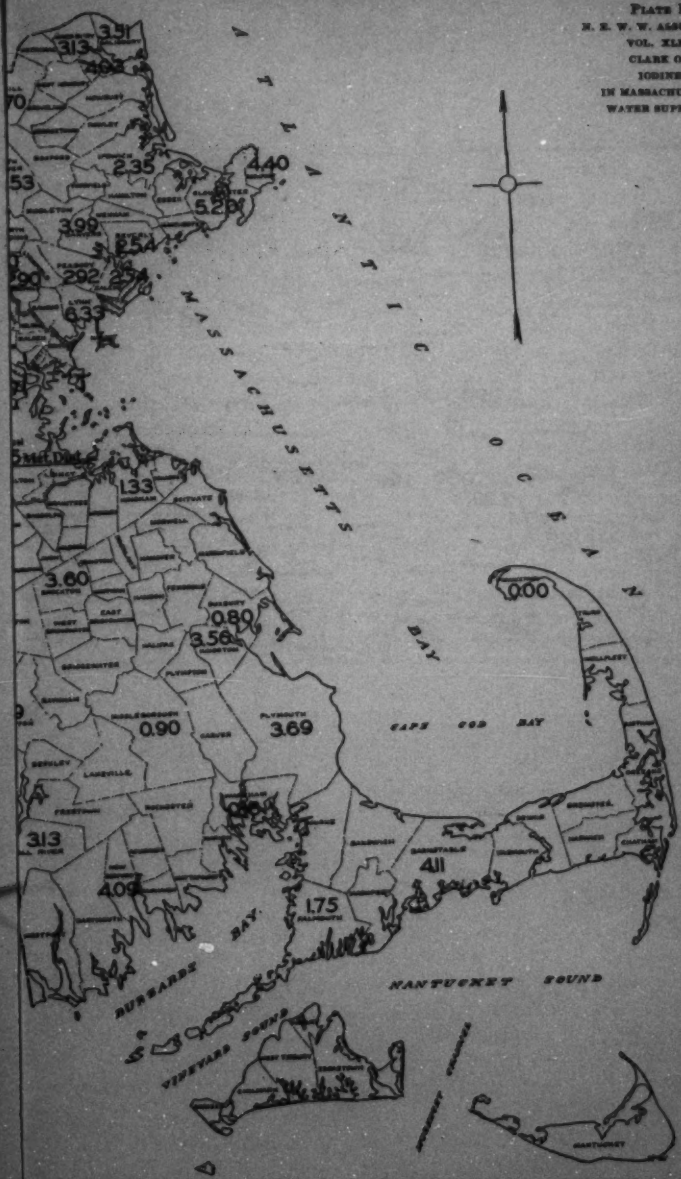

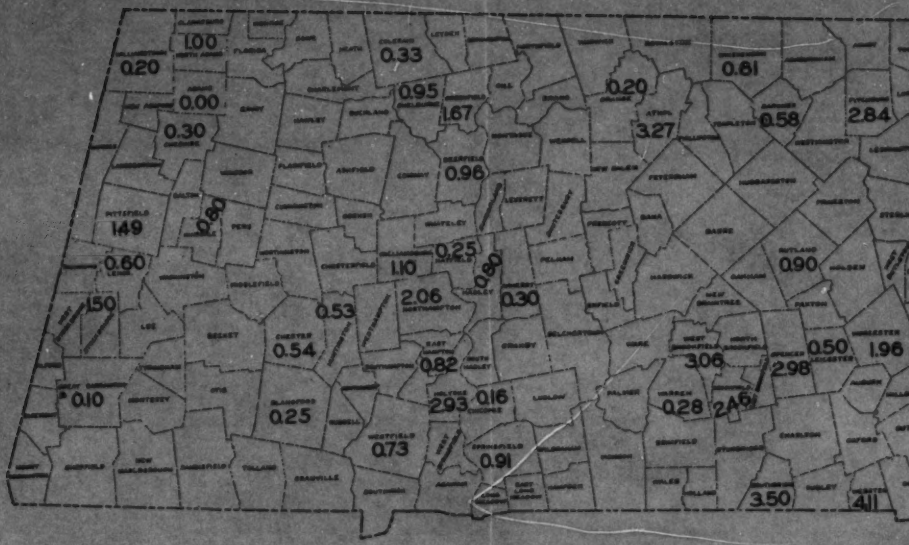

COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC HEALTH
MAP SHOWING

IODINE IN WATER SUPPLIES

PARTS PER BILLION

PLATE I.
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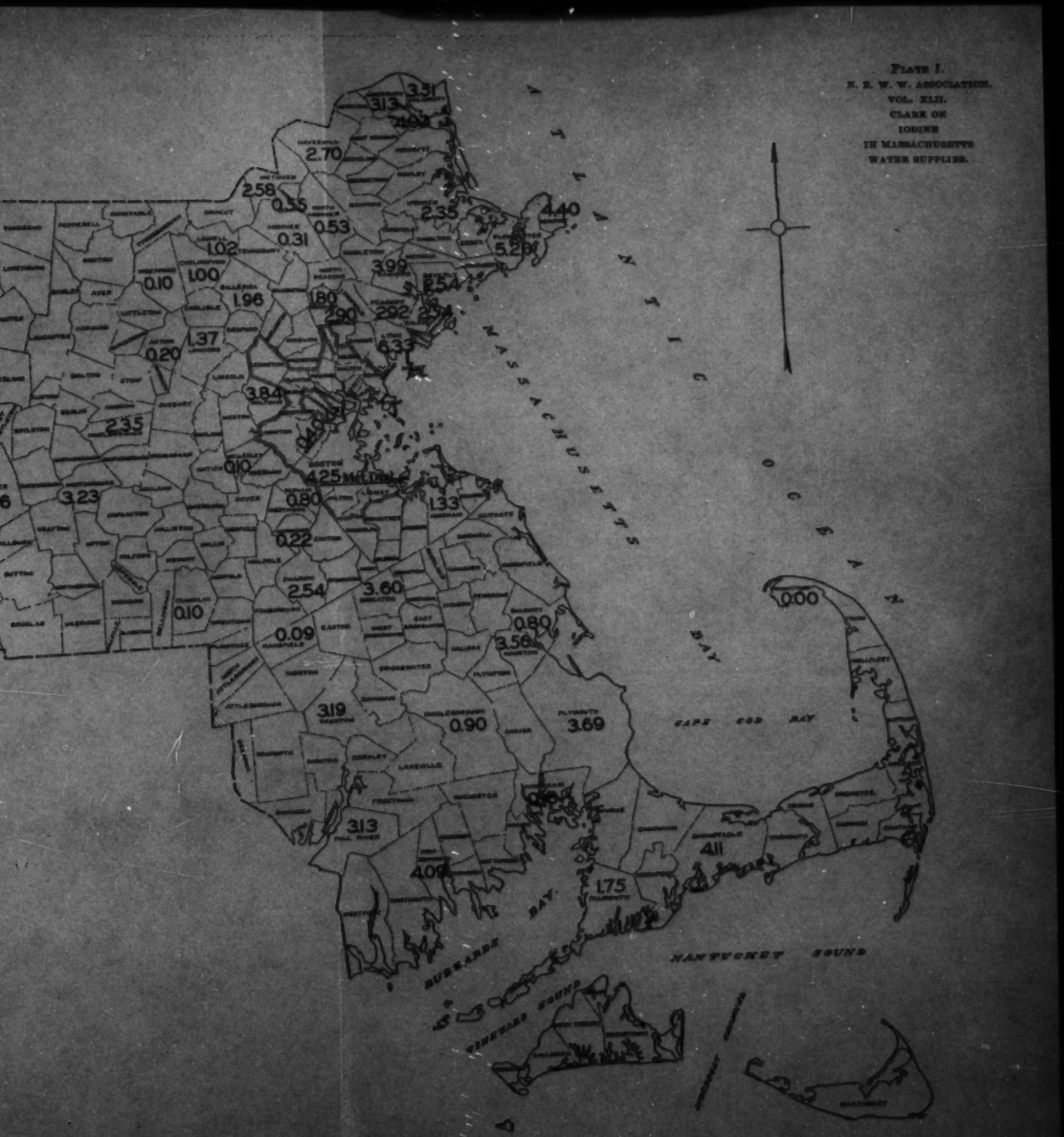

The geology of Massachusetts is very different from that of the central west and northwest where up to the present time the largest amount of work in this country upon iodine in waters has been carried on. A large part of the central west, northwest and south, is over large areas much more uniform in its geological formation than is New England. Much of the soil of certain areas of this region was through the ages taken by erosion from the higher land areas and deposited in vast level, or nearly level, areas once the bottom of an inland sea. Some of this eroded soil was from earth and rocks nearly iodine-free, while other portions were taken from iodine-containing materials. Moreover, as this salt water became concentrated by evaporation certain large areas were uncovered by its withdrawal, while in or over other areas, deposits of sea salt containing iodine were formed during the final evaporation of this salt water. It would be natural therefore to find in certain areas a much greater amount of iodine than in any Massachusetts soil or water, and also a greater uniformity in the iodine constituents of this soil over considerable areas than could be expected in Massachusetts. Certain Michigan waters, for instance, contain iodine amounting to from 50 to 100 parts per billion and chlorine up to several thousand parts per million. No results such as these can be found with Massachusetts waters. Certain other large areas of the west and northwest apparently have little or no iodine-bearing soil or rock, and hence the waters of such areas are lower in iodine than the average of Massachusetts waters. Massachusetts is a comparatively small state with a very uneven surface, hills and valleys succeeding each other rapidly; its soil, sand and rocks were left or deposited very largely by the glacial drift and the character of these rocks and the soil varies greatly over limited areas.

During the glacial epoch the warm climate of the Tertiary was replaced by a climate similar to that of Greenland, and a mantle of ice, rising above the tops of the highest mountains, moved southward across the state, deeply scouring the rocks and carrying much rock material, coarse and fine. As the climate became more severe the thick water-soaked layer of rotted rock which had come to form the surface became frozen, and as the snow accumulation increased and became the glacial ice, perhaps a mile thick over New England, the whole ultimately moved forward and the softened rock layer became the first and principal source of the till. The peculiar stiff clay or hardpan called till, full of unsorted bowlders of different sizes, many of them angular, scratched, and far traveled, which was in many places compressed almost like rock by the great weight of the ice, was left on the melting of the ice as an irregular veneering over most of the surface.*

Certain of the soils and sands are of the Tertiary formation but covered by the glacial drift, and some of the rocks and soils from both formations are apparently comparatively rich in iodine, while other Massachusetts rocks and soils have little or no iodine to yield to the solvent power of water. The water taken from driven wells in deposits of gravel and certain sandy areas which some of the water reaches after passing over and through cer-

*Geology of Massachusetts and Rhode Island by B. K. Emerson, U. S. Geological Survey, 1917, pp. 134 and 135.

tain soil will contain iodine owing to the character of the soil, gravel and rocks in this gathering ground, while the water from other wells driven in sand which is almost pure silica, contains no iodine, as this sand apparently has none to yield in spite of its proximity to the sea. The surface waters also vary greatly in their iodine content owing to the different character of the rocks and soils upon the various watersheds. The amount of iodine found in the surface waters of the state varies from none to 6.33 parts per billion and in the ground waters from none to 4.30 parts per billion. Speaking broadly, more iodine has been found in the waters of the eastern part of the state than in those of the western part, but 5.86 parts per billion were found during a dry period in one supply in the Connecticut River valley and 2.18 parts per billion in one of the most western supplies of the state; on the other hand, certain supplies in the eastern part of the state contain little or no iodine. That the amount of iodine now present in our supplies has any appreciable increment from rain or mists or fogs from the ocean, does not seem probable as we have been unable to find more than .005 part per billion of iodine in rain water collected fifteen miles from the seashore, and this amount may have been due to some impurity accidentally introduced during the collection of the fifty gallons necessary for this determination. This seems probable, as two other samples of fifty gallons collected in the same area were found to be free of iodine.

We are of course not dependent upon water for iodine, as many vegetables and grains contain it in large amounts and sea fish, especially certain species, are great carriers of iodine, as are marine growths, seaweeds, mosses, etc. When we began to study this question of iodine in Massachusetts water supplies we also began to determine the amount of iodine in fish and other foods, but found that so much work along this line had been done that we soon discontinued these food studies although we had determined that much iodine was present in cod, mackerel and other salt-water fish. The iodine content of sea foods has been quite thoroughly studied by the Bureau of Fisheries of the United States Department of Commerce and two bulletins issued several years ago by that bureau give many results of determinations of iodine in both fresh and preserved or salted sea foods. Some of this food contains nearly 10 000 parts of iodine per billion, and in the fifty or more sea fish examined by the Bureau of Fisheries it varied from 390 parts per billion in tuna fish to 9 600 parts in oyster liquor. Von Fellenberg found 900 000 parts per billion of iodine in dry seaweed and amounts varying from 2 to 448 parts per billion in fruits, watercress, butter, eggs, corn, wheat, etc. Many others have done similar work and obtained similar results.

The method for determining iodine used by us has been that of McClendon given in the *Journal of Biological Chemistry*, Vol. LX, No. 2, June, 1924, but with a few variations, as follows: — In the volume of water taken (thirty gallons), evaporation to dryness and ignition, McClendon has been followed exactly. The amount of Na_2CO_3 needed to keep the waters alkaline to phenol-red paper during evaporation, however, together with the

amount of mineral and organic matter concentrated by evaporation of the water, made it impossible to dissolve the ash in 15 c.c. of water as advised by him, and the volume of this solution of ash was usually about 25 c.c. Further, all of this solution was used as it did not seem good prac-

IODINE IN MASSACHUSETTS WATER SUPPLIES.

(Results are stated in parts per billion.)

Surface Waters.

Adams	0.00	Greenfield	1.67	Pittsfield	1.49
Amherst	0.30	Hadley	0.80	Plymouth	3.69
Andover	0.31	Hatfield	0.25	Rockport	4.40
Athol	3.27	Haverhill	2.70	Rutland	0.90
Blandford	0.25	Hinsdale	0.80	Salem-Beverly	2.54
Brockton	3.60	Holyoke	2.93	Sharon	2.54
Brookfield	2.46	Huntington	0.53	Shelburne Falls	0.95
Cambridge	1.71	Ipswich	2.35	Southbridge	3.50
Cheshire	0.30	Lawrence	0.55	Spencer	2.98
Chester	0.54	Lenox	0.60	Springfield	0.91
Chicopee	0.16	Lynn	6.33	Stockbridge	1.50
Colerain	0.33	Marlboro	2.35	Taunton	3.19
Concord	1.37	Metropolitan District	4.25	Wakefield	2.90
Danvers	3.99	New Bedford	4.09	Warren	0.28
Fall River	3.13	North Adams	1.00	Westfield	0.73
Falmouth	1.75	Northampton	2.06	Williamsburg	1.10
Fitchburg	2.84	North Andover	0.53	Williamstown	0.20
Gardner	0.58	Norwood	0.22	Worcester	1.96
Gloucester	5.20	Orange	0.20		
Great Barrington	0.10	Peabody	2.92		

Ground Waters.

Acton	0.20	Franklin	0.10	Reading	1.80
Amesbury	3.13	Hingham	1.33	Salisbury	3.51
Barnstable	4.11	Kingston	3.56	Waltham	3.84
Billerica	1.96	Leicester	0.50	Wareham	0.16
*Brookline	0.40	Lowell	1.02	Webster	4.11
Chelmsford	1.00	Mansfield	0.09	Wellesley	0.10
Dedham	0.80	†Methuen	2.58	Westboro	3.23
Deerfield	0.96	Middleboro	0.90	West Brookfield	3.06
Duxbury	0.80	†Newburyport	4.03	Westford	0.10
Easthampton	0.82	‡Provincetown	0.00	Winchendon	0.61

*Receives some Metropolitan water but this determination is of the ground water supply.
†Mixture of ground water and Spicket River water.
‡Three determinations.

tice to evaporate 100 liters and then use only an aliquot portion. With waters low in iodine the entire sample was necessary for proper readings. With the larger volume of solution to extract, larger volumes of carbon tetrachloride were used than by McClendon and the color read in an aliquot portion. The procedure for determining the iodine in this carbon tetrachloride extract was in other respects exactly the same as McClendon's. Carbon tetrachloride was purified as McClendon recommends,

but tests on a c.p. carbon tetrachloride showed that further purification was unnecessary.

The preceding table presents the results of nearly all of the iodine determinations made by us, some of doubtful value not being included, and in a number of instances averages of several determinations of certain supplies are given. The towns from which samples were taken are also indicated on the accompanying map of the state, together with the amount of iodine found.

The careful and skilful analytical work necessary to determine the minute amounts of iodine found was performed by Mr. George O. Adams and Mr. William J. Magee.

THE RAINFALL OF NEW ENGLAND.

PART I. ANNUAL RAINFALL.*

BY J. HENRY WEBER.†

The only previous work dealing with the rainfall of New England in any detail is that of X. H. Goodnough in 1915[1]. Mr. Goodnough, who is the Chief Engineer of the Massachusetts Department of Public Health, has collected all rainfall data that have hitherto been published in the reports and bulletins of the U. S. Weather Bureau, the New England Meteorological Society, the reports of water departments of cities and towns and the annals of academies and colleges. In addition many records were found in other publications and a few were obtained from original manuscripts that hitherto had not been made public. All these data were published in the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, September, 1915[2], and brought up to date in September, 1921[3], and June, 1926[4]. In addition to presenting tables of the rainfall of 241 New England stations in the 1915 publication, Mr. Goodnough has presented valuable information concerning the historical observations of rainfall in New England, two diagrams showing the progressive average rainfall over a long period of years in Massachusetts, average monthly rainfall diagrams for the principal watersheds in the area and a map and discussion of the mean annual rainfall of New England. This mean annual rainfall map was based mainly on records covering a period of 40 years, 1873–1913. The isohyets were drawn for every two inches. Areas of higher rainfall are shown in western Massachusetts and Connecticut, central Massachusetts, the Narragansett Basin and the White Mountain district. Only in western Connecticut and in the White Mountain district are amounts above 50 in. indicated. The Champlain Lowlands, the north central portion of Vermont and the northern portion of the Kennebec River Valley, are the principal areas of low rainfall shown. In these regions the amounts are below 36 in., with the lowest rainfall, 30 in., in the northwestern portion of Vermont. No attempt was made to indicate the mean annual rainfall in northern Maine.

Data Utilized. The data used in the present study were compiled from Mr. Goodnough's tables, with a few additions from Bulletin W[5] and Climatological Data[6].

Records were tabulated for 313 stations in New England and for 22 stations in the adjoining regions of New York, Quebec and New Brunswick for the period, 1881–1925, inclusive. These stations and the number of years of record are shown in Table 2.

* Editor's Note: This is the first of a series of four papers by J. Henry Weber on "The Rainfall of New England."

†Clark University, Worcester, Mass.

Individual missing months in these records were supplied through interpolation of the values of one or more nearby stations for the month in question, although in a few cases missing values were supplied by direct substitution of the values of a nearby station. Stations thus completed, with from 3 to 44 years of record, falling within the 1881–1925 period, were adjusted to a 45-year basis by establishing ratios for the missing years[7]. In a few instances adjustments were not deemed feasible and the original values were used without change. In other instances adjustments were made on stations reporting for less than 45 years. In nearly all of the above mentioned cases, however, the stations in question had reported during at least 35 of the 45 years.

The data thus made available for mean values are summarized in Table 1.

TABLE 1.

NUMBER OF RAINFALL STATIONS AND LENGTH OF RECORD.

(Forty-five-year period, 1881–1925, Inclusive.)

	Length of Record — Years.						Total.
	45	35–44	25–34	15–24	5–14	Under 5	
Maine	5	3	5	10	10	5	38
New Hampshire	5	3	8	8	13	1	38
Vermont	2	3	6	5	14	2	32
Massachusetts	24	14	26	16	74	1	155
Connecticut	6	7	5	3	8	0	29
Rhode Island	2	6	0	2	6	0	16
New York	2	2	5	2	0	0	11
Quebec	2	1	0	1	1	0	5
New Brunswick	1	0	1	0	4	0	6
Total	49	39	56	47	130	9	330

There were also five additional stations, all in northern New England, that were tabulated and used in some cases for maximum and minimum annual values.

Acknowledgments. The writer wishes to express his indebtedness to Dr. Charles F. Brooks, under whose direction the work was done, and to the Graduate School of Geography at Clark University.

MAPS OF ANNUAL RAINFALL AND THEIR INTERPRETATION.

Mean Annual Rainfall (Plate I). The greater portion of New England has a mean annual rainfall (including melted snow, sleet, and hail) of between 40 and 45 in. The mean values for stations with 45 years of record vary, however, from 47.29 in. at Canton, Conn., to 31.78 in. at Burlington, Vt.; stations with shorter records indicate values varying from 82.21 in. at Mount Washington, N. H., (16–20-year record unadjusted) to the adjusted value of 29.1 in. at Houlton, Me. (See Table 2.)

30
35
40
45
50
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PLATE I.
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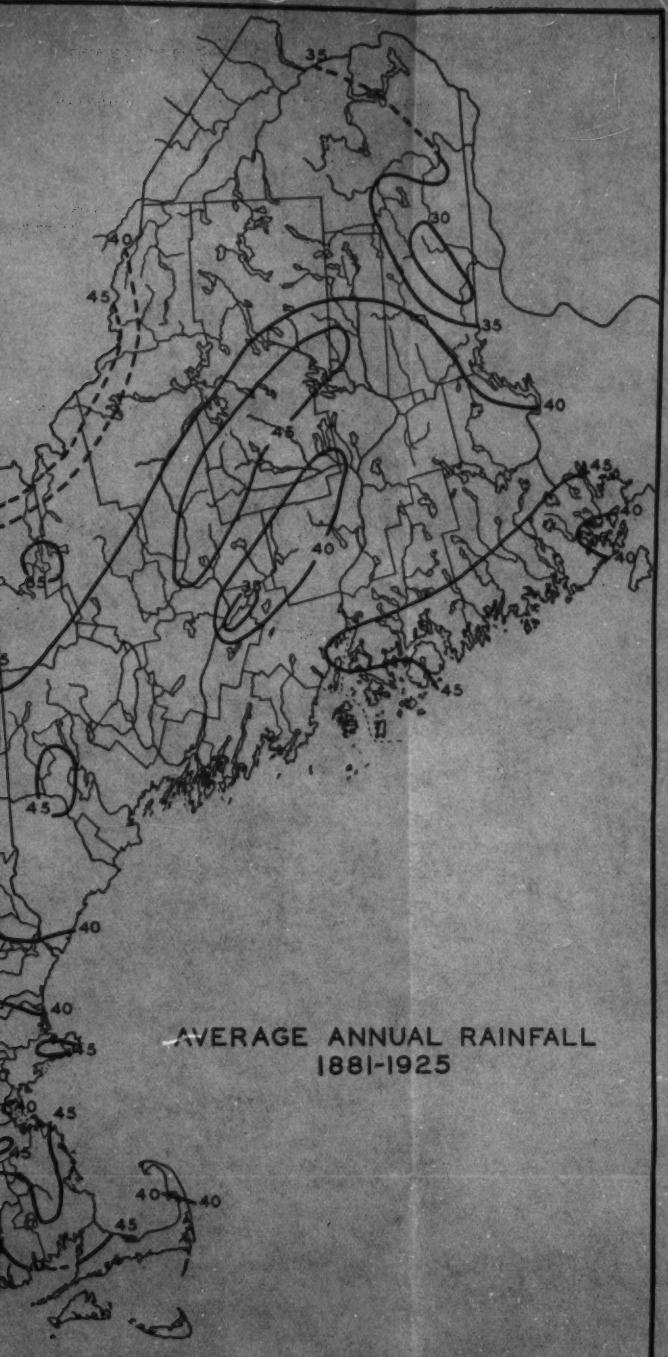
NEW ENGLAND.



AVERAGE ANNUAL RAINFALL
1881-1925

ADAPTED FROM MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH'S MAP OF NEW ENGLAND - X. H. GOODNOUGH CHIEF ENGINEER
DRAWN BY G. H. BURNHAM, CARTOGRAPHER, GRADUATE SCHOOL OF GEOGRAPHY, CLARK UNIVERSITY, WORCESTER, MASS.

TABLE 2.

THE MEAN ANNUAL RAINFALL OF STATIONS IN NEW ENGLAND.

Maine.

Station.	Elevation. (Feet.)	Number of Years of Record.	Mean Annual Rainfall. (Inches.)	Station on which adjusted.
Ashland	...	4	34.8	Houlton
Azischos Dam	...	15	36.8	Upper Dam
Bar Harbor	20	35	49.0	Eastport
Belfast	165	13	45.1	Portland
Calais	120	13	47.7	Eastport
Camden	...	12	42.4	Portland
Cornish	778	43	46.86	None
Danforth	390	8	40.0	Orono
Eastport	53	45	38.94	....
Fairfield	90	30	34.4	Gardiner
Farmington	450	35	43.5	Gardiner
Flagstaff	1 400	15	36.7	Upper Dam
Gardiner	163	45	42.36	....
Greenville	1 000	20	45.5	Orono
Houlton	362	21	29.1	Fredericton, N.B.
Jackman	...	4	38.3	Upper Dam
Kineo	1 060	4–9	34.0	Mayfield
Lewiston	185	45	43.47	....
Livermore	338	15	43.0	Lewiston
Madison	257	24	46.1	Gardiner
Mayfield	1 000	15	46.7	Orono
Middle Dam	1 430	21	35.1	Upper Dam
Millinocket	129	26	44.0	Orono
Milo	...	4	39.4	Orono
N. Bridgton	450	32	44.9	Lewiston
Old Town	95	12	42.3	Orono
Oquossoc	1 534	9	38.9	Upper Dam
Orono	129	45	41.24	....
Patten	550	16	40.3	Orono
Portland	99	45	42.33	....
Presque Isle	1 000	12	36.2	Fredericton, N. B.
Rumford Falls	505	32	41.1	Lewiston
Songo	280	10	42.5	Portland
The Forks	580	14	40.6	Orono
Upper Dam	1 470	40	32.78	None
Van Buren	510	17	36.9	Fredericton, N. B.
Winslow	90	30	38.5	Gardiner
Woodland	...	6	43.6	Eastport
Wytopitlock	...	8	40.3	Orono

TABLE 2 (Continued).

THE MEAN ANNUAL RAINFALL OF STATIONS IN NEW ENGLAND.

New Hampshire.

Station.	Elevation. (Feet.)	Number of Years of Record.	Mean Annual Rainfall. (Inches.)	Station on which adjusted.
Alstead	1 120	29	40.0	Hanover
Belmont	600	12	40.0	Lakeport
Berlin	...	15	37.0	Errol
Berlin Mills	1 100	25	37.6	Errol
Bethlehem	1 470	33	38.4	Hanover.
Bristol	600	9	41.5	Lakeport
Brookline	250	26	42.4	Fitchburg
Concord	350	45	37.36	....
Durham	88	31	40.4	Lawrence
Errol	1 260	41	37.49	None
Fitzwilliam	1 110	6	45.4	Fitchburg
Franklin	440	24	42.1	Concord
Glencliff	1 650	16	42.9	Plymouth
Gorham	...	15	34.6	Errol
Grafton	863	36	38.3	None
Hanover	603	45	34.91	....
Keene	506	34	38.2	Fitchburg
Lakeport	500	45	42.14	....
Littleton	1 032	8	38.8	Plymouth
Manchester	200	45	39.21	....
Mt. Washington	6 293	16–20	82.21	None
Nashua	125	42	39.33	Lowell
Newton	200	29	40.0	Lawrence
North Conway	575	13	41.2	Cornish
Peterboro	744	11	40.4	Fitchburg
Pittsburg (a)	1 575	8	40.8	Errol
Pittsburg (b)	1 575	8	45.0	Errol
Plymouth	500	45	40.29	....
Profile	...	4	50.9	Plymouth
Sanbornton	830	10	37.7	Lakeport
Stratford	1 000	21	36.6	Errol
Weirs	500	16	40.5	Lakeport
West Milan	1 016	11	40.0	Errol
West Stewartstown	1 050	12	31.2	Errol
Wolfboro	500	16	41.9	Lakeport
Woodstock	1 050	8	48.0	Plymouth
Woodville	750	8	34.9	Hanover

TABLE 2 (Continued).

THE MEAN ANNUAL RAINFALL OF STATIONS IN NEW ENGLAND.

Vermont.

Station.	Elevation. (Feet.)	Number of Years of Record.	Mean Annual Rainfall. (Inches.)	Station on which adjusted.
Bellows Falls	300	12	35.0	Hanover
Bennington	720	3	40.8	Williamstown
Bloomfield	900	19	36.9	Errol
Brattleboro	335	15	40.9	Amherst
Burlington	404	45	31.78	....
Cavendish	910	22	38.4	Woodstock
Chelsea	840	40	35.57	None
Cornwall	507	39	31.2	Burlington
Enosburg Falls	601	34	39.4	Burlington
Fitzdale	850	7	30.3	St. Johnsbury
Garfield	1 300	6	40.1	Northfield
Guildhall	875	12	32.4	St. Johnsbury
Halifax	900	12	40.9	Williamstown
Hyde Park	576	6	38.9	Northfield
Jacksonville	1 000	28	44.4	Williamstown
Londonderry	1 000	12	36.1	Williamstown
Manchester	980	15	41.1	Williamstown
Morrisville	690	3	....	....
Northfield	876	38	32.94	None
Norwich	550	32	37.2	Hanover
Readsboro	1 220	9	48.0	Williamstown
Ryegate	480	12	33.6	St. Johnsbury
St. Johnsbury	711	32	34.87	None
Somerset	2 096	14	52.5	Williamstown
Strafford	500	17	38.9	Woodstock
Vernon	310	32	40.2	Amherst
Victory	800	4	38.0	St. Johnsbury
Wells	750	27	38.5	Williamstown
West Hartland	665	14	39.6	Hanover
West Rutland	562	9	33.4	Cornwall
White River Jct.	400	12	33.3	Hanover
Wilmington	1 500	7	47.4	Williamstown
Woodstock	700	45	38.12	....

Massachusetts.

Station.	Elevation. (Feet.)	Number of Years of Record.	Mean Annual Rainfall. (Inches.)	Station on which adjusted.
Acushnet	50	45	46.73	....
Agawam	410	12	49.0	Springfield
Amherst	222	45	43.69	....
Ashby	1 000	11	46.5	Fitchburg
Ashland	250	36	43.44	Westborough
Athol	1 000	14	40.3	Fitchburg
Attleborough	100	25	44.7	Taunton
Barre	930	6	45.2	Princeton
Bedford	170	31	39.6	Concord
Belchertown	440	16	41.4	Ludlow
Blue Hill (Summit)	640	40	46.23	Chestnut Hill

TABLE 2 (Continued).

THE MEAN ANNUAL RAINFALL OF STATIONS IN NEW ENGLAND.

Massachusetts (Continued).

Station.	Elevation. (Feet.)	Number of Years of Record.	Mean Annual Rainfall. (Inches.)	Station on which adjusted.
Blue Hill (Valley)	60	33	44.4	Chestnut Hill
Boston	124	45	39 53	....
Boylston	530	30	46.3	Clinton
Bridgewater	60	11	45.0	Taunton
Brockton	200	32	40.73	Taunton
Cambridge	75	45	41.68	....
Charlton	880	5	42.4	Webster
Chester	600	13	44.6	Canton, Conn.
Chesterfield	1 360	6	46.2	Pittsfield and Amherst
Chestnut Hill	124	45	45.25	....
Clinton	300	45	42.76	....
Cohasset	50	8	46.8	Hingham
Colrain	500	13	44.2	Williamstown
Concord	139	35	40.9	Waltham
Cotuit	60	8	42.1	New Bedford
Cummington	1 400	6	46.7	Pittsfield and Amherst
Dalton	1 200	20	42.9	Pittsfield
Dana	580	5	45.4	Leicester
Danvers	100	14	41.6	Wenham
Deerfield	140	5	44.1	Amherst
Dudley	450	34	42.8	Webster
Easthampton	200	9	53.0	Amherst
Egremont	750	19	43.3	Pittsfield
Fall River	210	45	45.22	....
Falmouth	70	7	45.4	New Bedford
Fitchburg	625	45	41.88	....
Framingham	160	45	43.88	....
Gardner	1 100	19	45.5	Fitchburg
Gilbertville	560	8	49.3	Leicester
Gloucester	40	11	47.1	Lynn
Granville (a)	750	13	47.4	Canton
Granville (b)	950	12	52.6	Canton
Greenwich	490	6	46.6	Amherst
Groton	325	36	42.0	Fitchburg
Hardwick	950	5	42.9	Leicester
Haverhill	125	31	40.5	Lawrence
Heath	1 650	6	47.1	Williamstown
Hingham	70	40	45.02	Chestnut Hill
Holden	750	40	45.00	Leicester
Holyoke	90	28	47.1	Springfield
Hubbardston	1 030	6	42.6	Princeton
Huntington	500	6	47.3	Canton, Conn.
Hyannis	31	34	43.5	New Bedford
Ipswich	30	14	45.9	Wenham
Lakeville	60	32	45.32	Taunton
Lawrence	51	45	41.30	....
Leeds	350	20	47.65	Amherst
Leicester	800	45	43.63	....
Leominster	500	41	43.37	Fitchburg
Littleton	325	8	37.6	Clinton
Lincoln	187	20	39.0	Waltham
Lowell	100	45	43.78	....
Ludlow	410	45	41.44	....
Lynn	40	45	41.03	....
Manchester	20	13	42.6	Lynn
Mansfield	150	11	48.6	Taunton

TABLE 2 (Continued).

THE MEAN ANNUAL RAINFALL OF STATIONS IN NEW ENGLAND.

Massachusetts (Continued).

Station.	Elevation. (Feet.)	Number of Years of Record.	Mean Annual Rainfall. (Inches.)	Station on which adjusted.
Marlborough	450	26	41.5	Framingham
Medford	17	10	41.9	Waltham
Middleboro	53	38	43.9	Taunton
Middlefield	1 650	5	43.0	Pittsfield
Milford	275	11	41.1	Northbridge
Millis	130	5	42.8	Natick
Monroe Bridge	840	12	44.9	Williamstown
Monson	370	27	43.0	Springfield
Mount Nonotock	850	10	43.8	Springfield
Mt. Wachusett	2 000	...	50.2	Princeton
Nantucket	47	39	40.31	Block Island, R. I.
Natick	140	45	43.35	....
New Bedford	88	45	46.03	....
Newburyport	20	22	38.0	Lynn
Newton	100	18	42.1	Waltham
New Salem	850	6	44.6	Princeton
Norfolk	244	18	43.7	Natick
North Adams	1 000	26	43.4	Williamstown
North Andover	100	14	40.8	Lowell
North Billerica	100	20	41.3	Lowell
Northbridge	350	45	44.85	....
North Dana	520	6	44.0	Leicester
Norwood	90	13	42.6	Natick
Otis	1 400	13	45.5	Canton, Conn.
Peabody	75	14	44.1	Lynn
Pembroke	65	10	44.4	Taunton
Peru	1 700	13	45.9	Pittsfield
Petersham	1 100	10	45.0	Fitchburg
Phillipston	1 190	5	42.6	Fitchburg
Pittsfield	1 050	31	41.8	Williamstown
Plainfield	1 650	6	47.5	Pittsfield
Plymouth	50	39	45.97	Taunton
Prescott	1 000	10	45.2	Amherst
Princeton	1 125	37	45.10	Princeton
Provincetown	40	34–39	38.94	None
Quincy	20	13	43.2	Chestnut Hill
Reading	80	27	42.8	Wenham
Rochester	60	27	48.3	Acushnet
Rockport	30	23	43.1	Lynn
Rowe	1 300	8	42.9	Williamstown
Rutland	1 160	18	44.3	Leicester
Salem	20	25	41.2	Lynn
Savoy	2 000	13	47.3	Williamstown
Sharon	270	22	44.1	Natick
Shelburne Falls	300	11	40.2	Amherst
Shutesbury	1 175	6	49.0	Princeton
Somerset	40	38	44.33	Fall River
Somerville	60	17	42.3	Cambridge
Southampton	250	29	48.3	Amherst
Southboro	525	32	46.09	Westborough
Southbridge	720	14	43.9	Webster
Springfield	200	45	42.51	....
Sterling	500	29	43.0	Leicester
Stockbridge	875	6	42.6	Pittsfield
Stoneham	160	27	43.6	Waltham
Sturbridge	600	11	39.3	Webster

TABLE 2 (Continued).

THE MEAN ANNUAL RAINFALL OF STATIONS IN NEW ENGLAND.

Massachusetts (Continued).

Station.	Elevation. (Feet.)	Number of Years of Record.	Mean Annual Rainfall. (Inches.)	Station on which adjusted.
Taunton	50	45	47.67	....
Templeton	930	29	39.8	Fitchburg
Turners Falls	200	34	39.5	Amherst
Vineyard Haven	40	6	42.3	Block Island
Wakefield	100	8	42.9	Lynn
Walpole	90	24	41.7	Natick
Waltham	20	45	42.68	....
Ware	520	6	41.6	Leicester
Wareham	60	8	45.5	New Bedford
Warren	650	11	40.6	Leicester
Warwick	1 000	5	45.6	Princeton
Webster	450	45	42.83	....
Wellesley	160	8	44.8	Natick
Wendell	1 200	6	44.6	Princeton
Wenham	60	45	42.15	....
Westborough	298	45	43.97	....
West Brookfield	630	13	41.0	Leicester
Westfield	475	20	49.5	Canton
West Granville	1 200	13	48.5	Canton
Westhampton	750	7	48.1	Springfield
Westminster	880	11	49.4	Fitchburg
Weston	60	36	43.4	Waltham
West Roxbury	185	14	43.2	Boston
West Ware	450	6	41.8	Leicester
Williamsburg	550	13	43.6	Amherst
Williamstown	711	45	37.83	....
Winchendon	975	32	42.4	Fitchburg
Winchester	90	32	40.0	Waltham
Woods Hole	22	13	41.0	New Bedford
Worcester	400	30	40.78	Leicester
Worthington	1 500	9	46.8	Pittsfield
Wrentham	250	5	46.5	Taunton

TABLE 2 (Continued).

THE MEAN ANNUAL RAINFALL OF STATIONS IN NEW ENGLAND.

Connecticut.

Station.	Elevation. (Feet.)	Number of Years of Record.	Mean Annual Rainfall. (Inches.)	Station on which adjusted.
Bridgeport	20	32	47.38	New Haven
Burlington (a)	497	8	46.4	Canton
Burlington (b)	693	7	51.1	Canton
Canton	900	45	47.29	....
Colchester	370	34	49.5	Norwich
Cream Hill	1 300	29	46.6	Canton
Danielson	300	14	45.0	Hope
Enfield	90	10	44.7	Springfield
Fall Village	600	35	43.79	Canton
Greenwich	....	41	43.63	New Haven
Hartford	159	45	44.00	....
Hartland	1 200	9	51.6	Canton
Lake Konomoc	180	12	45.9	New London
Mansfield	640	20	44.2	Hartford
Middletown	125	45	46.63	....
Nepaug	690	13	48.1	Canton
New Hartford	399	13	46.1	Canton
New Haven	127	45	44.88	....
New London	47	45	43.58	....
Newtown	600	17	47.1	Boyds Corner, N. Y.
No. Grosvenordale	400	35	44.4	Webster
Norwalk	116	34	46.12	New Haven
Norwich	150	45	42.64	....
Simsbury	300	23	44.0	Canton
Southington	140	40	43.25	Middletown
Torrington	625	16	47.0	Canton
Voluntown	260	39	46.32	Norwich
Wallingford	130	35	47.20	Middletown
Waterbury	400	39	47.27	Middletown

Rhode Island.

Station.	Elevation. (Feet.)	Number of Years of Record.	Mean Annual Rainfall. (Inches.)	Station on which adjusted.
Block Island	26	45	41.21	....
Bristol	53	39	41.88	Fall River
Cranston	260	9	47.5	Providence
Foster	450	10	48.4	Providence
Greene	450	15	46.7	Voluntown
Hope	200	38	48.32	Providence
Hopkinton	120	10	50.8	Norwich
Kingston	250	37	52.14	New London
Lonsdale	116	19	45.7	Providence
Narragansett Pier	22	36	46.23	New London
Pawtucket	90	41	46.04	Providence
Providence	162	45	46.96	....
Scituate	440	10	46.2	Providence
South Scituate	280	10	48.0	Providence
Wallum Pond	40	8	44.7	Webster
Woonsocket	160	40	47.05	Providence

An area of higher rainfall, over 45 in., extends from the neighborhood of the Croton watershed in eastern New York State into Connecticut whence it divides into two branches. One extends eastward to the Massachusetts coast and the other continues north and northeastward to southern Vermont and New Hampshire. In the eastern branch a small area in southern Rhode Island is enclosed by the 50-in. isohyet, where damp southerly winds strike the hills in an unobstructed sweep from the ocean. In the northern branch there are a number of wet spots, each of which, however, is smaller in extent than that of Rhode Island.

The coast of Rhode Island is not protected, as is the coast of Connecticut by Long Island. This condition is sufficient to account for a greater rainfall in southern Rhode Island, for here, particularly in the colder season, muggy southerly winds blowing freely off the ocean are forced upward, chilled, and made to yield more of their moisture than elsewhere along the coast. Here, owing to friction with the land, they lose velocity on coming ashore, and crowd upward. The rise of a few hundred feet directly back of the coast accentuates this process, as does also the usual cushion of cold air over the land. Inland a little way, there is no notable further increase in elevation, so the maximum rainfall is soon reached. For example, Narragansett Pier has a mean annual rainfall of 46.23 in., Kingston, seven miles inland, reports 52.14 in., and Hope, eighteen miles north of Kingston, has 48.32 in. A similar, but less marked condition, is indicated in southern Massachusetts and Connecticut.

In the northern branch the areas having a mean annual rainfall over 50 in. are at a considerable distance inland, and at relatively higher elevations, varying from 700 ft. in Connecticut to 2 000 ft. in southern Vermont. A record kept at the northern base of Mount Tom, in the Connecticut River Valley of Massachusetts, indicates a mean annual rainfall of 53 in. Heavier rainfall occurs here, particularly in the summer months, as the southerly winds give up abundant moisture in their forced ascent of Mount Tom. Bar Harbor, Me., at the northeastern base of Mount Desert, indicates a similar condition, except that the heavier precipitation comes in the winter months.

Except in the southern portion, observations are lacking in the higher portions of the Green Mountains, in Vermont. In the south there is a mean annual rainfall of over 50 in. at the higher elevations, but it is probable that the northern and central portions do not experience a mean annual rainfall of 45–50 in. except at the very highest elevations. This is because of a greater distance inland, higher latitude and the rain shadowing by the Adirondack Mountains and the White Mountains.

As far as observations show, the White Mountain district is the only other area in New England with a mean annual rainfall of 50 in. or over. Here, as in the Green Mountains, the number of stations are few, Mount Washington being the only rainfall station above 1 500 ft. elevation. This station, however, clearly shows the increase of rainfall with altitude, a

16–20-year record here indicating an average rainfall over 80 in. It is probable that most of the higher elevations in the White Mountains have a rainfall, similar to, though not so great as, that of Mount Washington.

The effect of elevation on the rainfall is again shown in the higher rainfall in the highlands of central and southwestern Maine and in the mountains along the New Hampshire, Maine and Quebec boundaries. Bar Harbor, Me., has a much higher rainfall than elsewhere in the region (49 in.), and it is possible that this area of higher rainfall might include the highlands east of Bangor, Me.

The most outstanding areas of lower rainfalls are the Lake Champlain lowlands, northeastern Maine and the Connecticut Valley and adjoining area in central Vermont. All these areas have a mean annual rainfall under 35 in. The Champlain lowlands are in the rain-shadow of the Adirondacks and Green Mountains; the Connecticut Valley region is in the rain-shadow of the Green and White Mountains. In the former area the lowest on the Vermont side is 31.2 in., at Cornwall, although in the adjoining region of New York State the mean annual amount falls below 30 in.; in the latter area the lowest is 32.2 in. at Northfield, Vt. In the Maine region a small area, Houlton, has under 30 in. of rainfall with a mean of 29.1 in., having the lowest mean annual rainfall in New England.

There are two small areas to the northeast of the higher elevation of the White Mountains, with a rainfall under 35 in., on the average; both are rain-shadows. In the northern portion of the Kennebec Valley in Maine and the southeastern portion of the Merrimack Valley and adjacent watersheds draining towards the coast, the rainfall diminishes considerably from the amount recorded in the surrounding areas. Only in the former area, however, does the average amount drop below 35 in.

The effect of the upwelling of cold water along the coast of Maine in reducing the precipitation, particularly in the summer months, is clearly shown at Eastport, where the mean annual amount falls below 39 in.; this is considerably lower than in the adjoining area. In the Narragansett Basin, on Cape Cod and on the islands of Martha's Vineyard, Nantucket and Block Island, water again plays its part in reducing the annual precipitation; in these regions, as at Eastport, the contiguous water bodies hinder the development and maintenance of convectional storms that play such an important rôle in the warm season rainfall. Bristol, on a peninsula in Narragansett Bay, has a mean annual rainfall of 41.9 in., while Kingston, eighteen miles to the south-westward, and Hope, fifteen miles to the westward, have 52.1 and 48.3 in., respectively. From the vicinity of the Cape Cod Canal to Provincetown the rainfall decreases more than 9 in. For instance, at Rochester, the mean annual amount is 48.3 in., at Hyannis, near the center of Cape Cod, 43.5 in., while at Provincetown the amount falls to 38.9 in.

The variation in the mean annual rainfall in the Boston Basin and vicinity is considerable. At Boston the weather-bureau station indicates

a mean annual rainfall of 39.53 in., at Cambridge the amount is 41.68 in. and at Chestnut Hill, Brookline, 45.23 in. The greater distance from the cold harbor and the slight rise in the land to the west of Boston, seem sufficient to account for the greater rainfall at Chestnut Hill, although the poor location of the Boston rain-gage on the roof of the Post Office building, may be an additional factor. On the summit of Blue Hill, elevation 640 ft., the annual rainfall, 46.2 in., is nearly two inches higher than the 44.4 in. at the base, elevation 60 ft.

Absolute Maximum Annual Rainfall (Plate II). The greater portion of New England has at some time during the period of record experienced an annual rainfall between 55 and 60 in., and all portions, with the exceptions of the Champlain lowlands, northeastern Maine and the Connecticut Valley in northern Vermont and New Hampshire, have recorded over 45 in. It will be noted that these same three areas have the lowest mean annual rainfalls in New England. In the first-named area, Cornwall reports its highest as 41.9 in., Houlton, in the second-named area, as 40.4 in., and St. Johnsbury, Vt., in the last-mentioned region, as 43.9 in. All of these stations have reported for less than the 45-year period under consideration, but examination of nearby stations seems to indicate that these values should be the maxima for the entire period. The maximum at each short-record station was compared with that of the nearest long-record station. If the year of greatest rainfall was the same for both stations then the maximum at the short-record station was taken as its maximum for the entire period. If, on the other hand, the year of greatest rainfall at the long-record station occurred before or since records existed at the shorter-record station, the difference between the maximum at the short-record station and the value recorded for the same year at the long-record station, was added or subtracted, as the case may be, to the absolute maximum amount recorded at the long-record station. This value was used as the probable maximum for the entire period at the short-record station.

The greatest annual rainfall recorded anywhere in this region is 121.13 in. at Mount Washington. In fact only one other station during the period covered by this study has ever recorded over 70 in., Kingston, R. I., reporting 72.2 in. An examination of all available earlier records in New England reveals that apart from the two stations mentioned, Brunswick, Me., is the only one to have over 70 in. of rainfall in a year; in 1845, 75.6 in. was recorded at this station. The general distribution of absolute maximum annual rainfall is in general accord with that of the average annual.

In southern New England, Provincetown, a place of low average rainfall, is the only station not to have recorded 50 in.

Absolute Minimum Annual Rainfall (Plate III). The annual rainfall has at some time during the period of record fallen below 40 in. at all stations with appreciable record with the exceptions of Mount Washington and Kingston, while the greater portion of the area has experienced under 30 in.

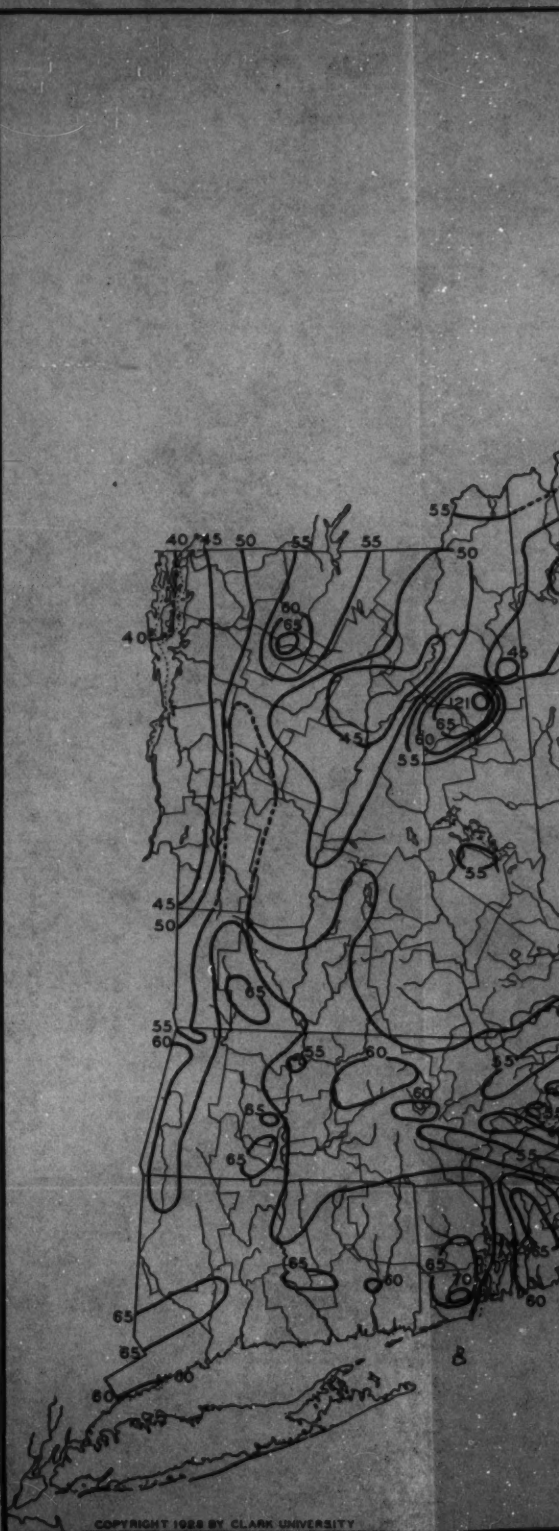


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PLATE II.
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WEBBER ON
RAINFALL OF
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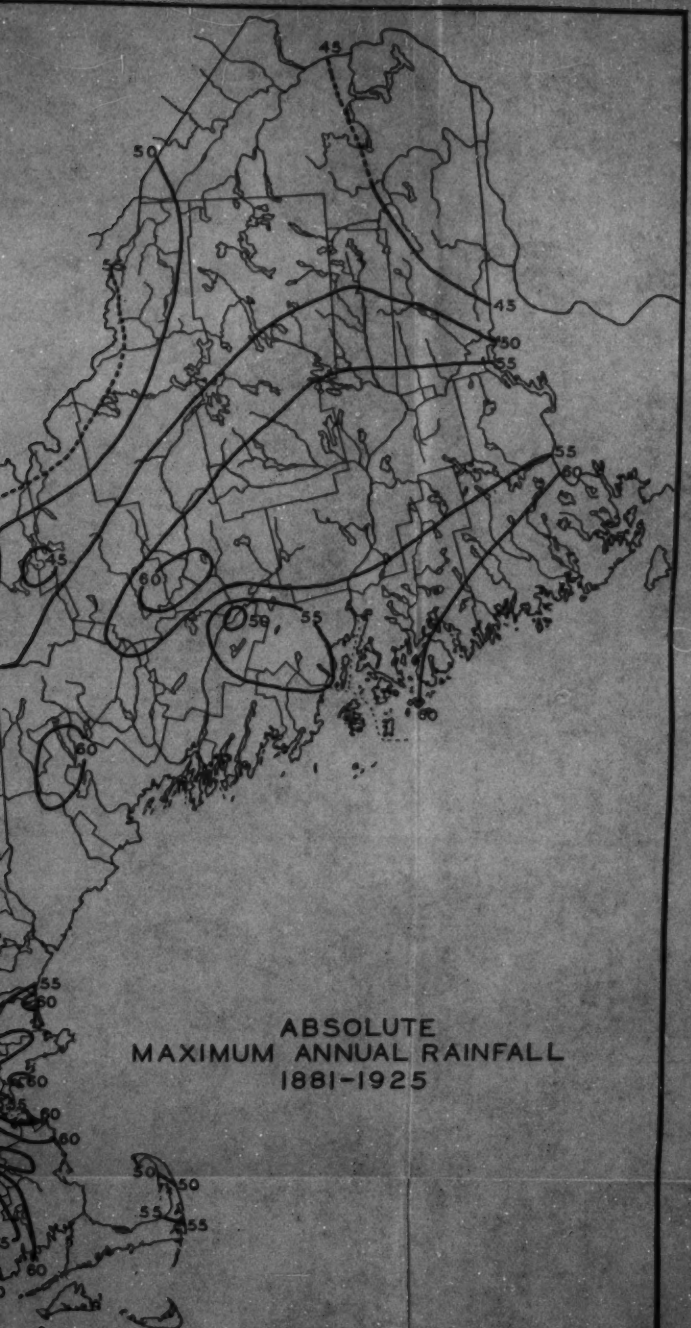

ABSOLUTE
MAXIMUM ANNUAL RAINFALL
1881-1925

ADAPTED FROM MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH'S MAP OF NEW ENGLAND - X. H. GOODNOUGH, CHIEF ENGINEER
DRAWN BY G.H. BURNHAM, CARTOGRAPHER, GRADUATE SCHOOL OF GEOGRAPHY, CLARK UNIVERSITY, WORCESTER, MASS.

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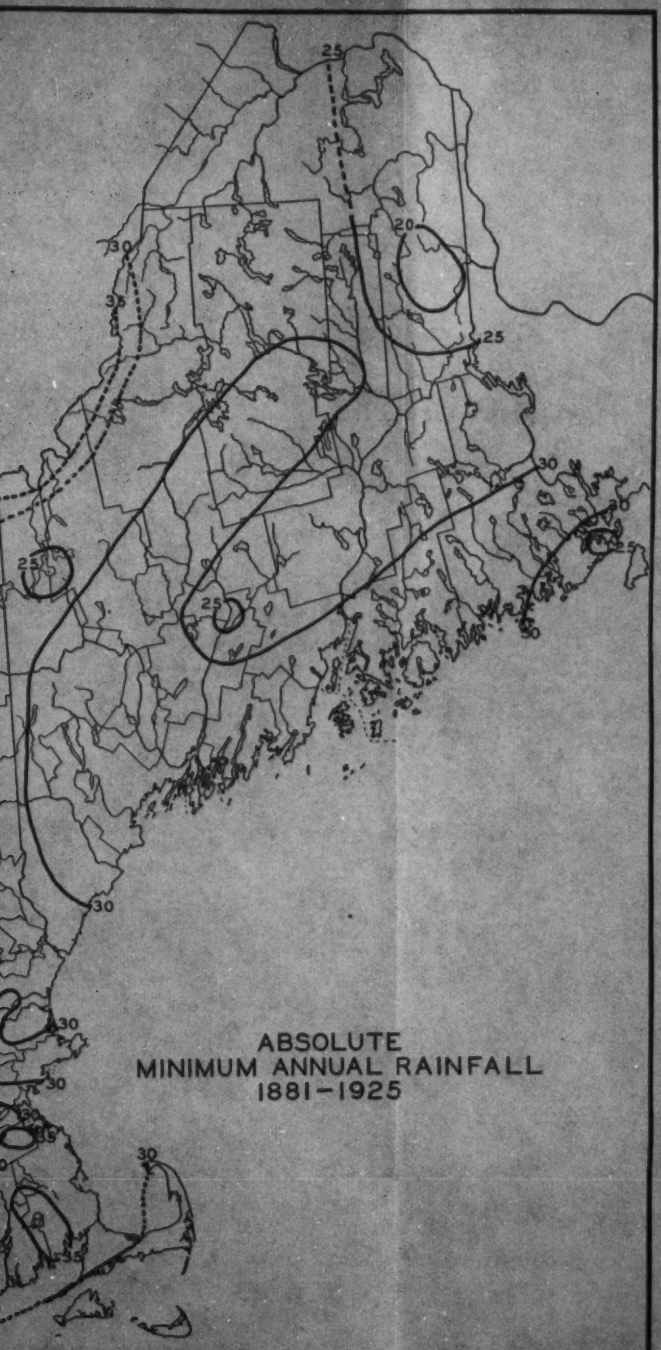

ABSOLUTE
MINIMUM ANNUAL RAINFALL
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ADAPTED FROM MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH'S MAP OF NEW ENGLAND – X. H. GOODNOUGH CHIEF ENGINEER
DRAWN BY G.H. BURNHAM, CARTOGRAPHER, GRADUATE SCHOOL OF GEOGRAPHY, CLARK UNIVERSITY, WORCESTER MASS.

RAINFALL IN NEW ENGLAND DURING THE STORM OF NOVEMBER 3 and 4, 1927.

BY X. H. GOODNOUGH.*

[*Read, January 11, 1928.*]

The great storm of November 3 and 4, 1927, caused the loss of many lives besides immense destruction of property in large sections of New England. The storm appears to have been general over the northeastern section of the country, extending from Pennsylvania and New York across New England and into Canada. The precipitation was greatest and its results most destructive in Vermont, including adjacent sections of New Hampshire, and in western Massachusetts. At the same time there was a secondary storm which extended from central Massachusetts southerly from the neighborhood of Clinton and Marlborough down the Blackstone valley and along the boundary line between Rhode Island and Connecticut to the sea near Westerly, R. I. The maximum precipitation in the northern storm was over 9 in. in southern Vermont, while in the smaller eastern storm an equal maximum precipitation occurred near the seashore at the Rhode Island-Connecticut boundary.

The area in which there was a precipitation of 9 in. or more amounted to about 457 sq. miles in Vermont and 40 sq. miles in Rhode Island and Connecticut. The rainfall exceeded 8 in. over an area of about 1 660 sq. miles in Vermont and about 135 sq. miles in the Rhode Island-Connecticut and Blackstone River region. The area with a rainfall of 6 in. or more amounted to 7 647 sq. miles in Vermont, New York, New Hampshire, Massachusetts and Connecticut and 827 sq. miles in the Blackstone River region in Massachusetts and in Rhode Island and Connecticut, a total of 8 474 sq. miles, nearly all in New England. This area is about equivalent to the area of the State of Massachusetts.

The areas in which the rainfall exceeded certain specified amounts in each state are given in Table 1. The isohyetal lines or lines of equal rainfall are shown in Plate I.

Such great rainfalls are rare within the limits of New England, but there is evidence that similar storms have occurred from time to time in the past, in some of which the precipitation may have been greater, though it is doubtful whether any similar storm in past years has caused such great loss of life and such destruction of property over so extensive an area as the storm of 1927.

The destructiveness of such a storm depends upon a number of circumstances, important among which are the character of the soil, the con-

*Chief Engineer, Massachusetts Department of Public Health.

All areas of 25 in. or lower are confined to northern New England while 20 in. or lower are found only in portions of western Vermont and in northeastern Maine. The lowest annual rainfalls recorded are: — Howe's Brook, Me., 16.35 in.; Manchester, Vt., 17.68 in.; Houlton, Me., 18.75 in.; Van Buren, Me., 21.65 in.; Upper Dam, Me., 22.40 in. and Jacksonville, Vt., 22.52 in. Burlington and Cornwall, Vt., and Eastport and Fairfield, Me., all have reported an annual rainfall under 23 in.

It is interesting to note that although Provincetown and Williamstown, Mass., both have a mean annual rainfall under 40 in., the annual rainfall during this 45-year period, has never fallen to 30 in. The maximum value at Williamstown is 54 in. and at Provincetown, 48 in.; contrast this slight variability with that of Jacksonville, Vt., where the mean annual rainfall is 44.4 in., the maximum, 66.9 in. and the minimum, 22.5 in.

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[5] U. S. Weather Bureau. Summary of the Climatological Data for the United States, by Sections. Washington, D.C. 1920, Sections 105 and 106.
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PLATE I.
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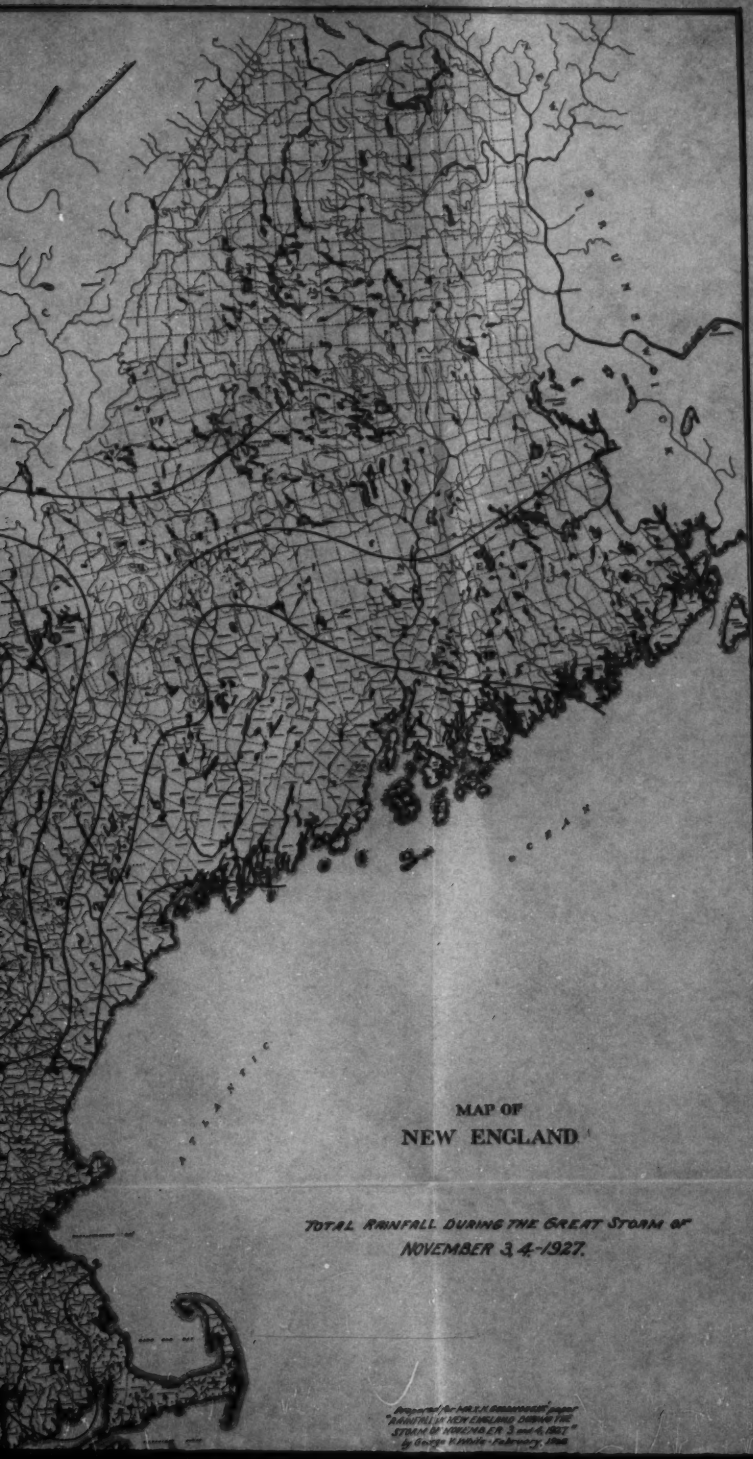
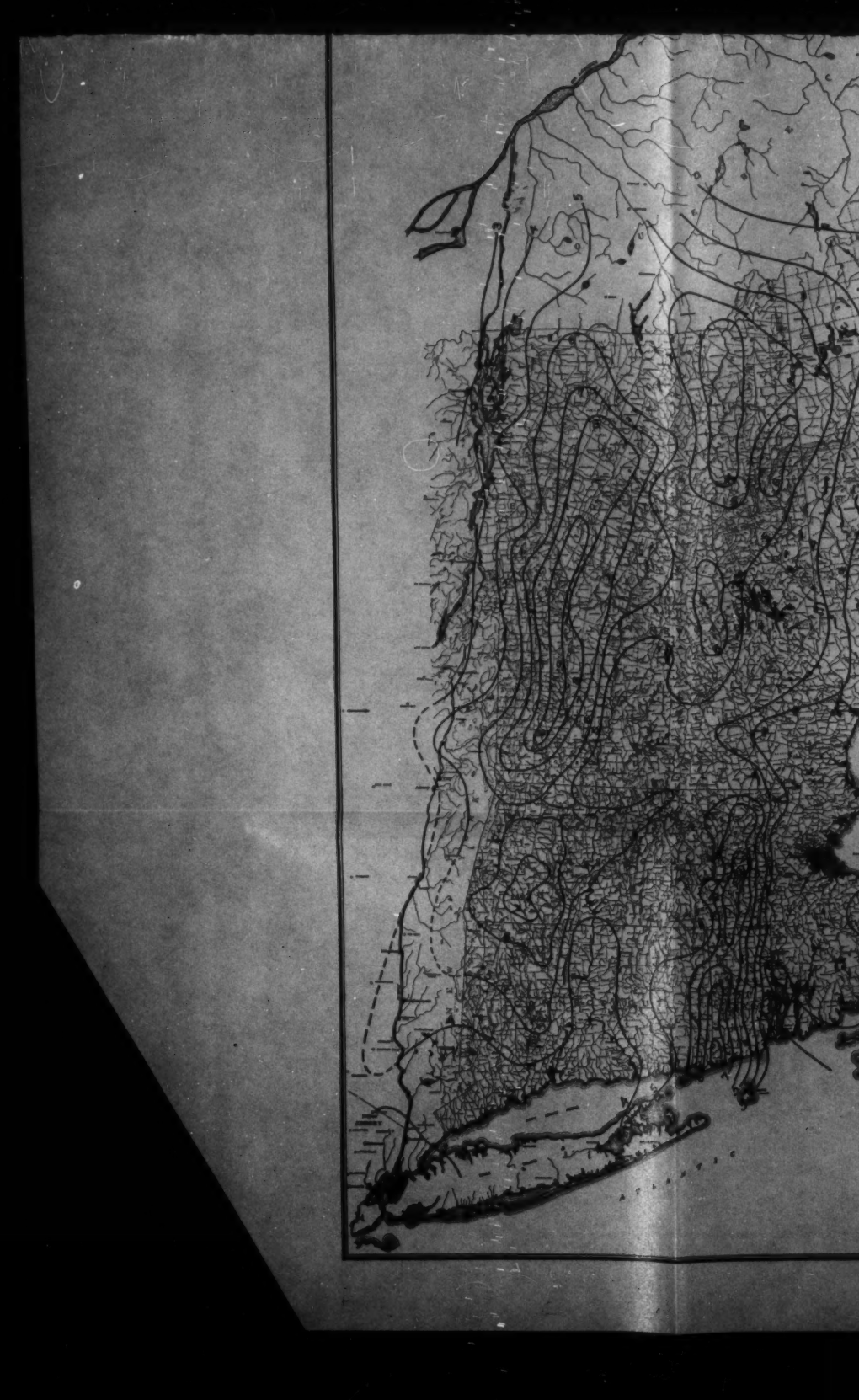
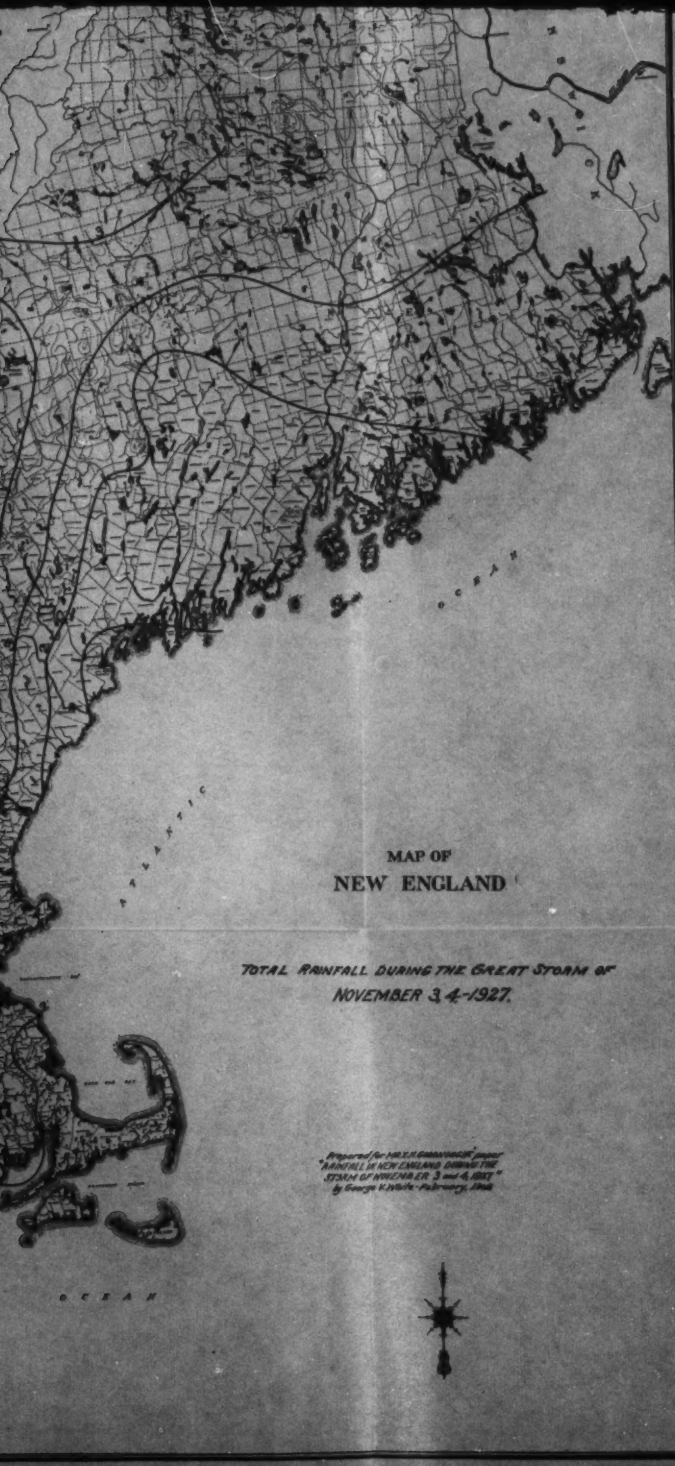
VOL. XLII.
GOODNOUGH ON
RAINFALL IN STORM OF
NOVEMBER, 1927.


MAP OF
NEW ENGLAND
TOTAL RAINFALL DURING THE GREAT STORM OF
NOVEMBER 3, 4-1927.
Prepared for Mr. D. K. Goodnough's paper
"RAINFALL IN NEW ENGLAND DURING THE
STORM OF NOVEMBER 3 and 4, 1927"
by George W. Wolfe - February, 1928.





MAP OF

NEW ENGLAND

TOTAL RAINFALL DURING THE GREAT STORM OF
NOVEMBER 3, 4-1927.

Prepared for the U.S. Geological Survey
"RAINFALL IN NEW ENGLAND DURING THE
STORM OF NOVEMBER 3 and 4, 1927."
by George K. White - February, 1928

tour and slope of the ground, the condition of the ground and of the streams and ponds at the time when the storm occurs, and the rate of precipitation. The rate of precipitation in this storm was excessive, and fortunately there is much information as to the rate of rainfall at many stations throughout the area affected. The records of the recording gages of the New England

TABLE 1.

AREAS FLOODED BY STORM OF NOVEMBER 3–4, 1927.

	Square Miles.
Over 9 inches.	
In Vermont	457
In Rhode Island and Connecticut	40
	497
Over 8 inches.	
In Vermont	1 660
In Massachusetts, Rhode Island and Connecticut	135
	1 795
Over 7 inches.	
In Vermont	3 320
In Massachusetts (Western)	220
In Massachusetts (Eastern)	130
In Rhode Island and Connecticut	372
	4 042
Over 6 inches.	
In Vermont and New York	5 530
In New Hampshire	715
In Connecticut	500
In Massachusetts (Western)	902
In Massachusetts (Eastern), and Rhode Island	827
	8 474
Over 5 inches.	
In Vermont and New York	8 135
In New Hampshire and Maine	8 300
In Western Massachusetts and New York	2 680
In Connecticut	920
In Massachusetts (Eastern), Rhode Island and Connecticut	1 999
	22 034

section of the Weather Bureau furnish very definite information as to the rates of precipitation at many places. Records were also made at other points by engineers of water-power companies, officials of water-works systems and other observers in the area covered by the storm. These records are shown in Tables 2, 5, 6 and 7, and in Figs. 1–26. From these records it appears that precipitation was practically continuous for from 28 to 40 hours, the bulk of the precipitation occurring in from 10 to 18 hours n most places. Some of these rates were very high. At Munroe Bridge n the Deerfield valley, rain fell at the rate of 0.28 in. per hour for 16 hours

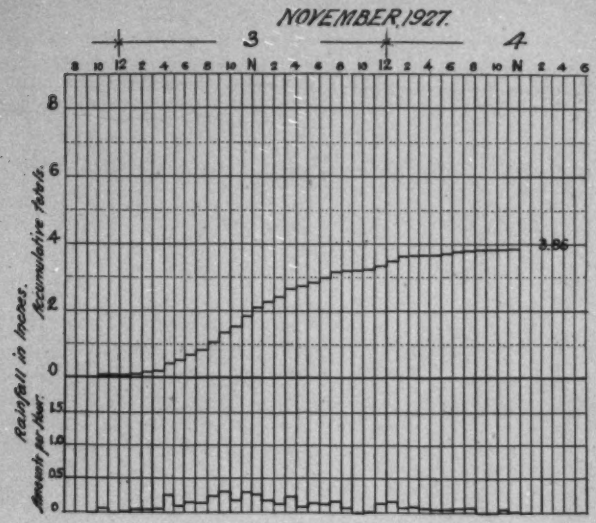


FIG. 1. — RAINFALL AT ALBANY, N. Y.

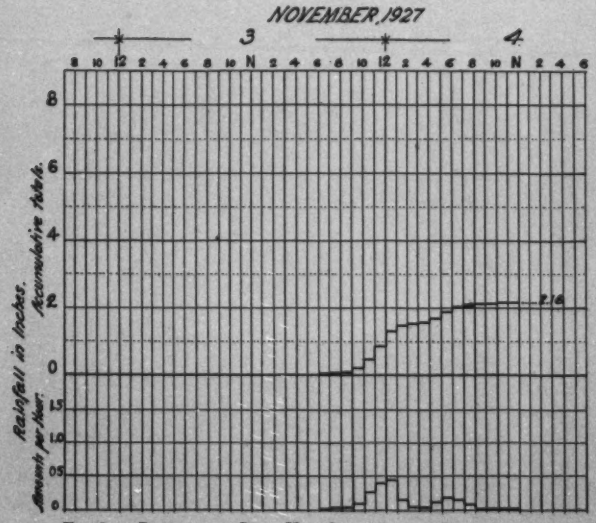


FIG. 2. — RAINFALL AT BLUE HILL OBSERVATORY, BOSTON, MASS.

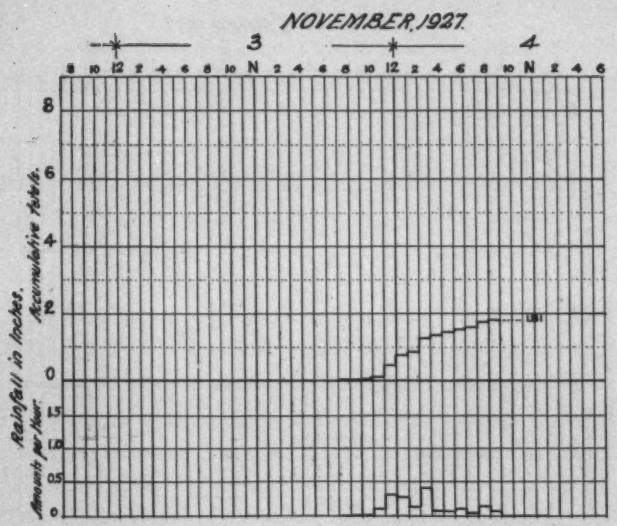


FIG. 3. — RAINFALL AT BOSTON, MASS. (U. S. WEATHER BUREAU.)

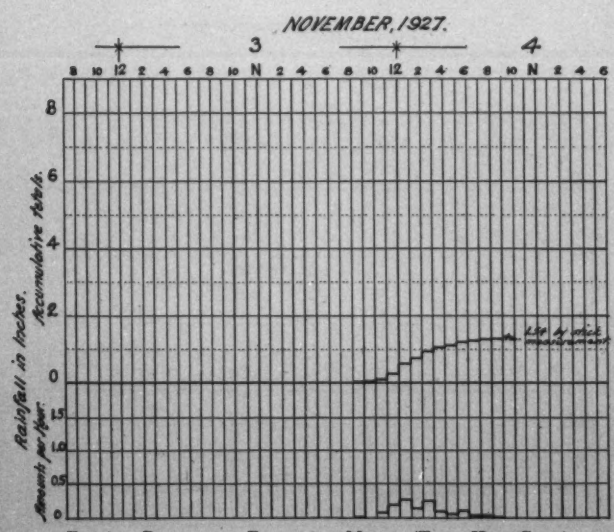


FIG. 4. — RAINFALL AT BROOKLINE, MASS. (TOWN HALL GAGE).

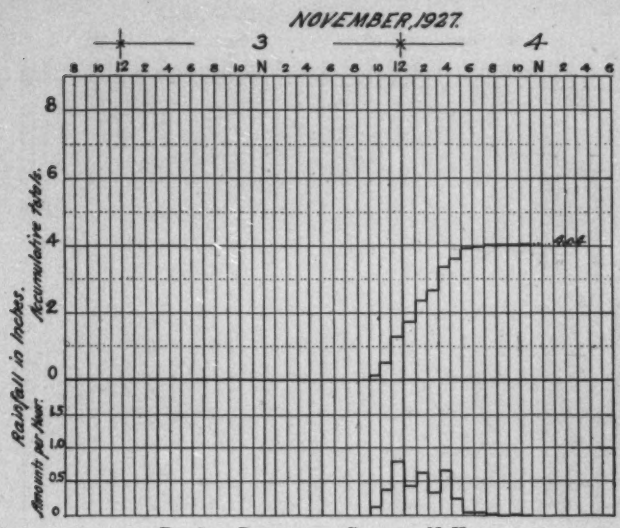


FIG. 5. — RAINFALL AT CONCORD, N. H.

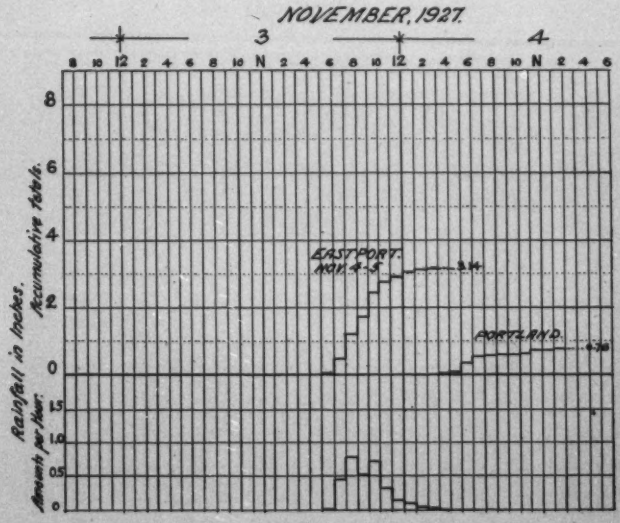


FIG. 6. — RAINFALL AT EASTPORT AND PORTLAND, ME.

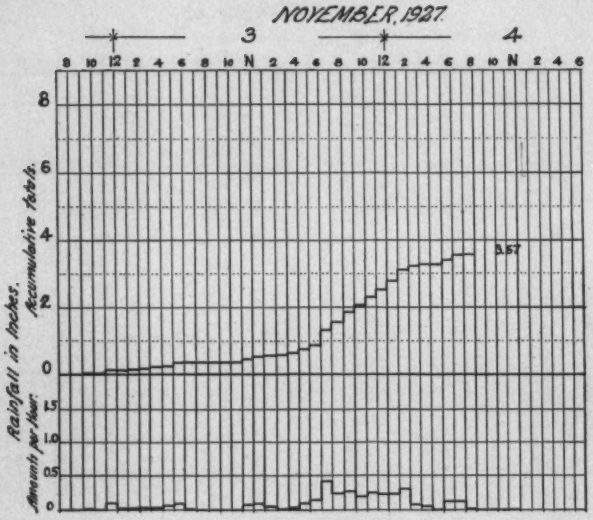


FIG. 7. — RAINFALL AT HARTFORD, CONN.

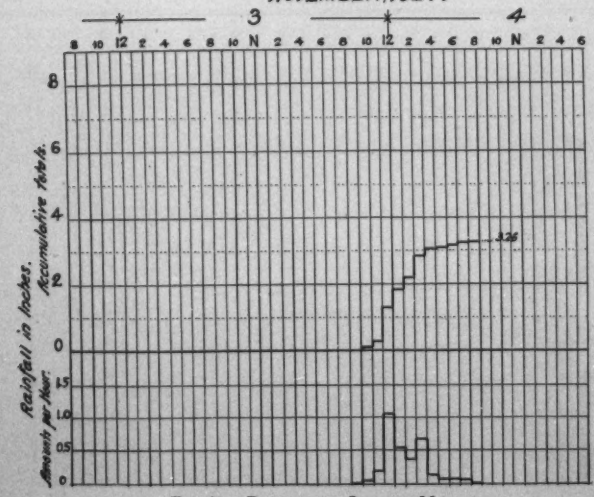


FIG. 8. — RAINFALL AT LOWELL, MASS.

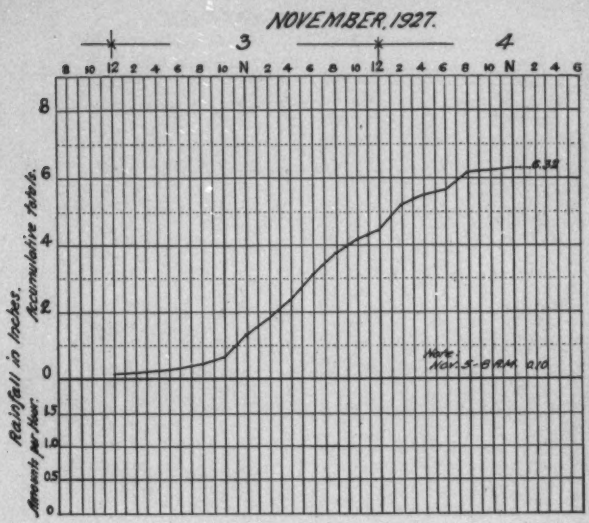


FIG. 9. — RAINFALL AT MONROE, MASS.

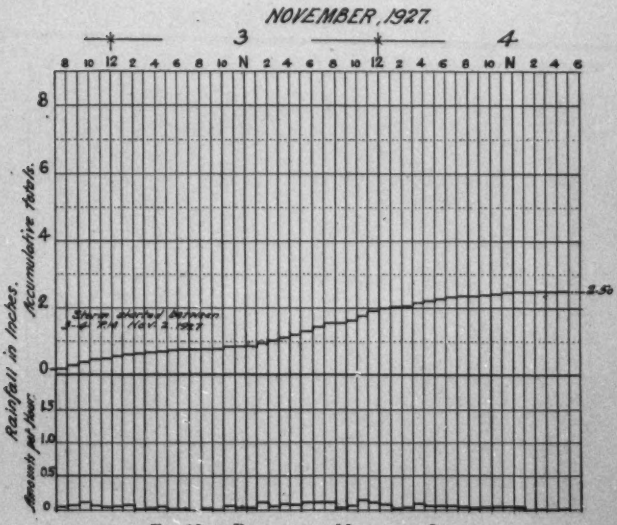


FIG. 10. — RAINFALL AT MONTREAL, QUE.

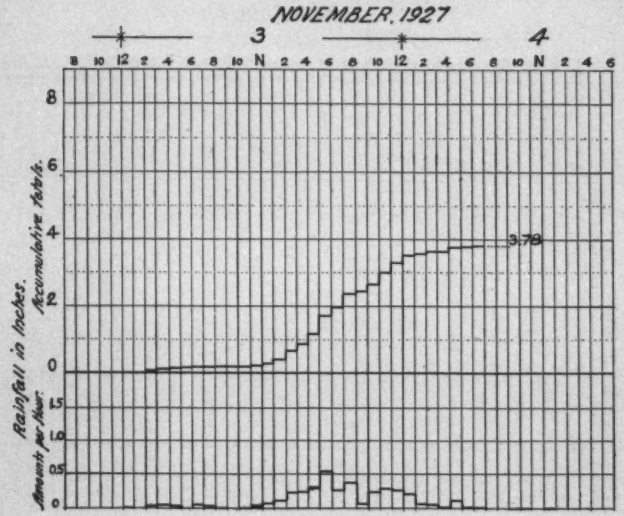


FIG. 11. — RAINFALL AT NEW HAVEN, CONN.

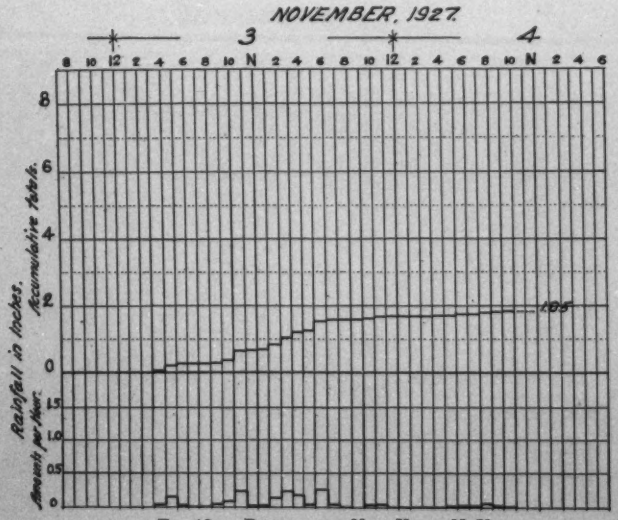


FIG. 12. — RAINFALL AT NEW YORK, N. Y.

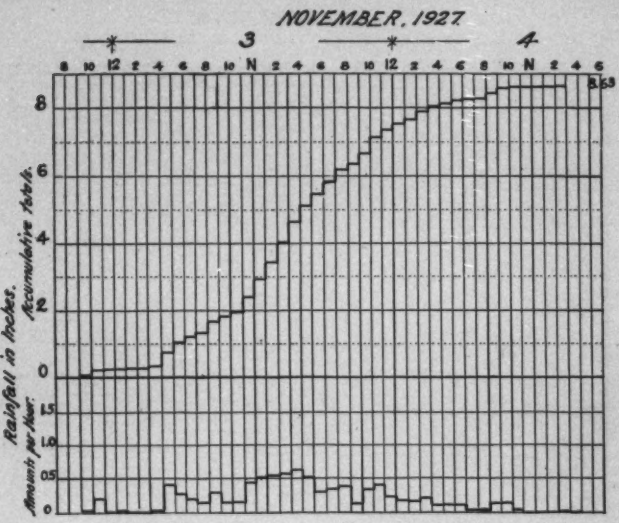


FIG. 13. — RAINFALL AT NORTHFIELD, VT.

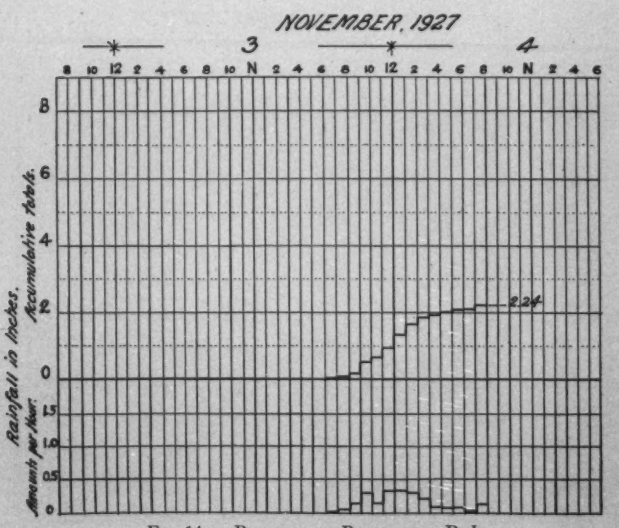


FIG. 14. — RAINFALL AT PAWTUCKET, R. I.

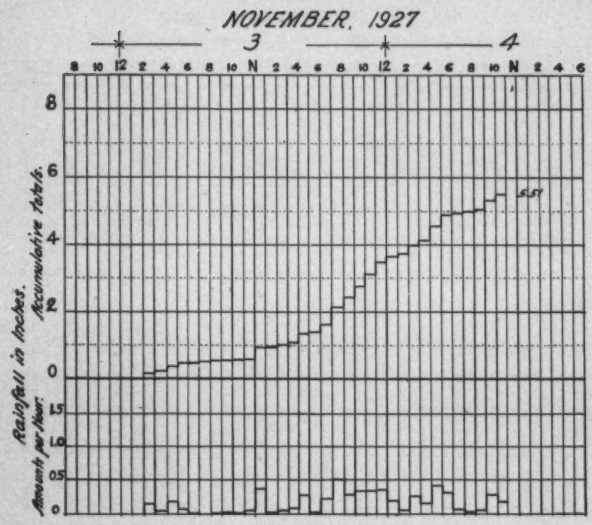


FIG. 15. — RAINFALL AT PHELPS BROOK DAM. (HARTFORD WATER WORKS, BURLINGTON, CONN.)

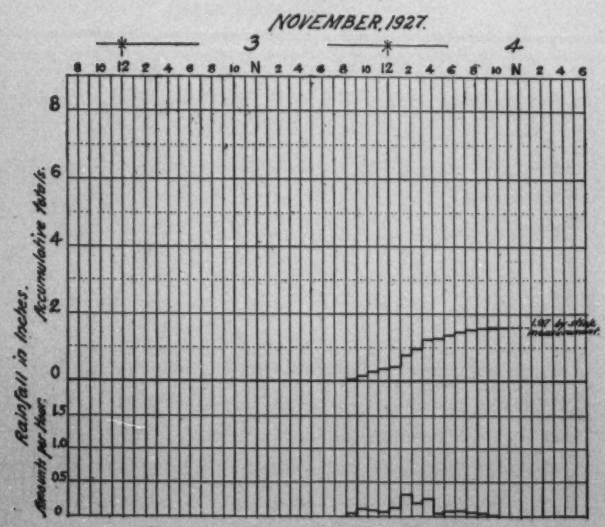


FIG. 16. — RAINFALL AT PROVIDENCE, R. I. (HOPE RESERVOIR.)

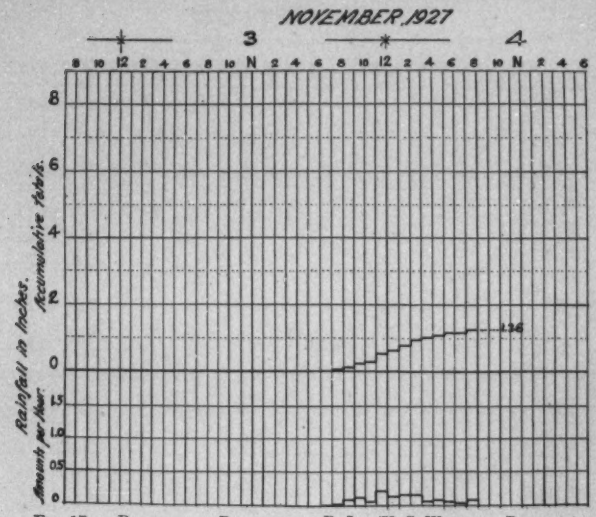


FIG. 17. — RAINFALL AT PROVIDENCE, R. I. (U. S. WEATHER BUREAU.)

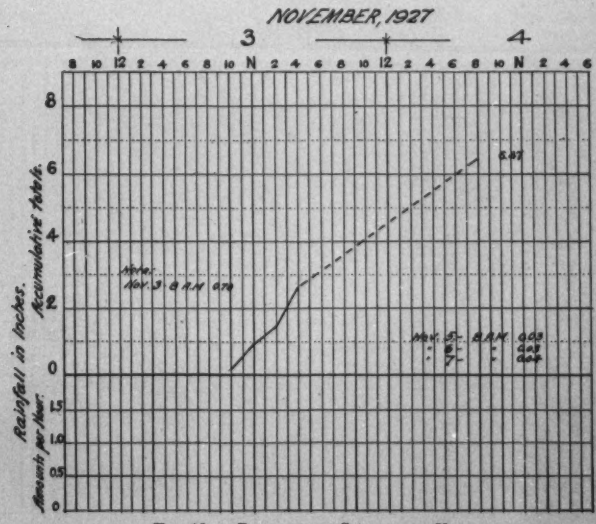


FIG. 18. — RAINFALL AT SEARSBURG, VT.

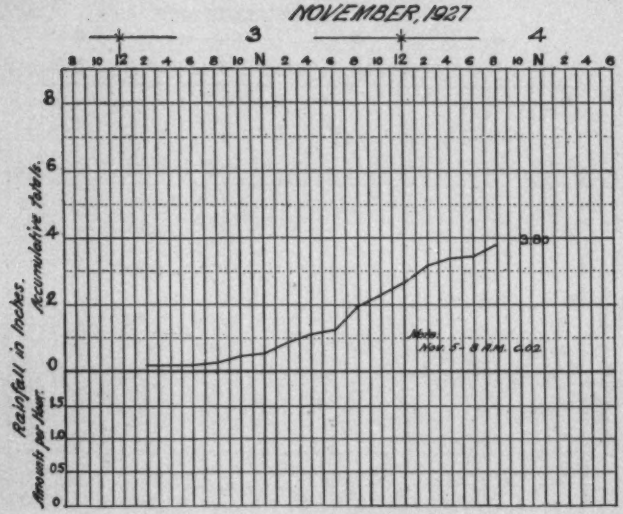


FIG. 19. — RAINFALL AT SHELBURNE FALLS, MASS.

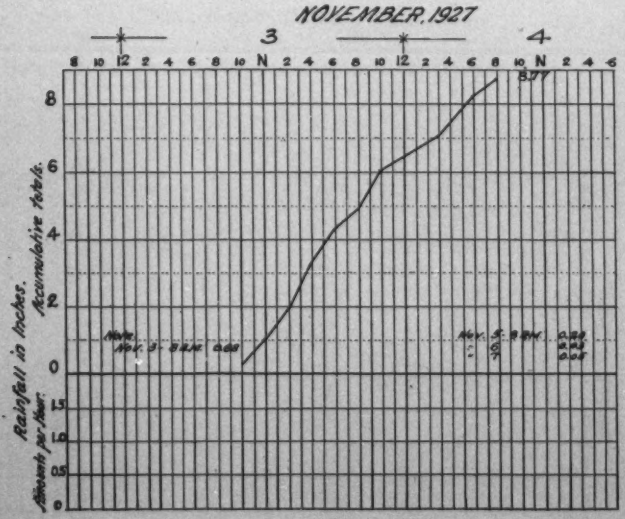


FIG. 20. — RAINFALL AT SOMERSET, VT.

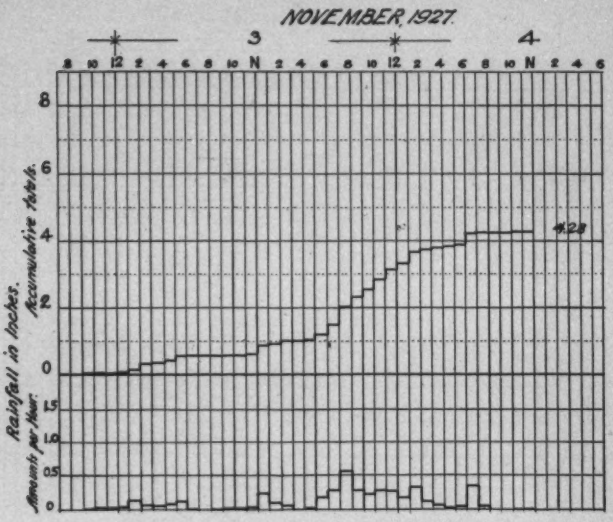


FIG. 21. — RAINFALL AT SPRINGFIELD, MASS.

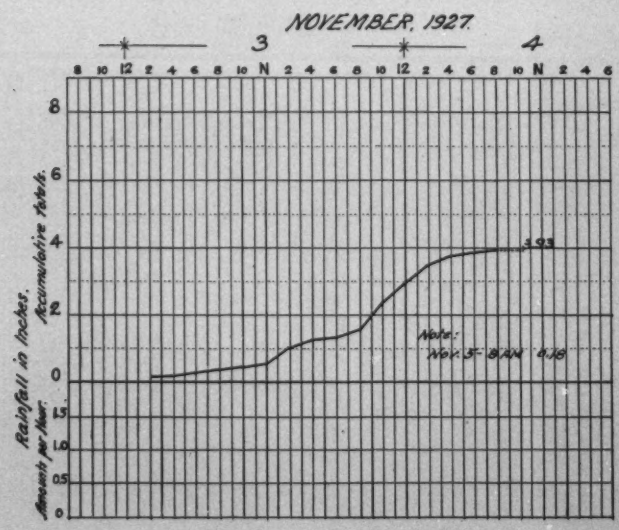


FIG. 22. — RAINFALL AT VERNON, VT.

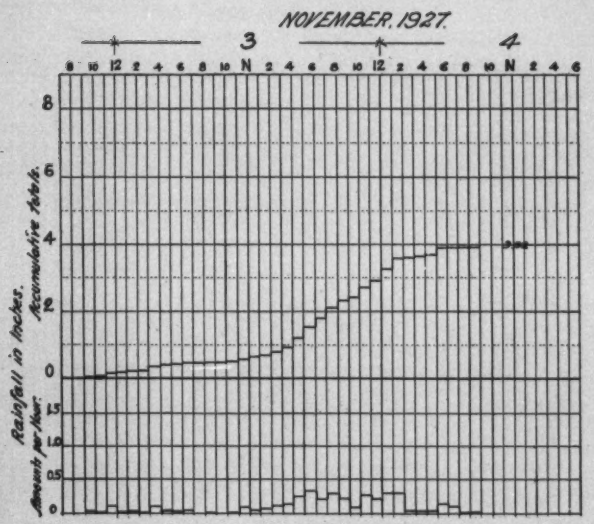


FIG. 23.—RAINFALL AT WEST HARTFORD FILTERS. (HARTFORD WATER WORKS, CONN.)

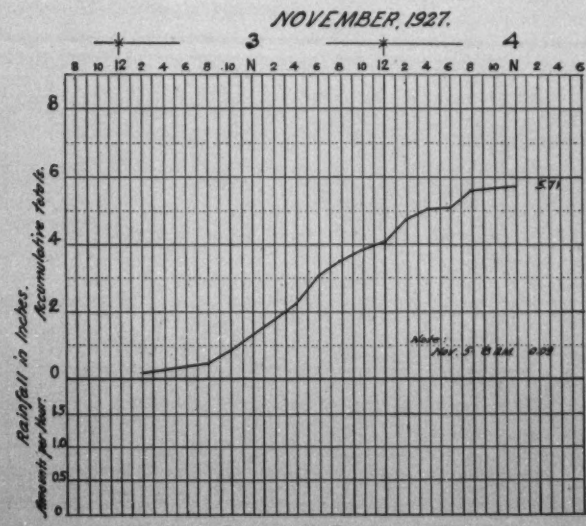


FIG. 24. — RAINFALL AT WHITINGHAM, VT.

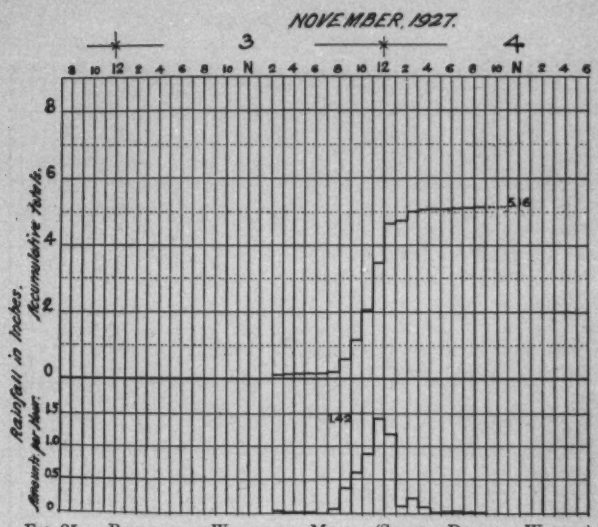


FIG. 25. — RAINFALL AT WORCESTER, MASS. (SEWAGE DISPOSAL WORKS.)

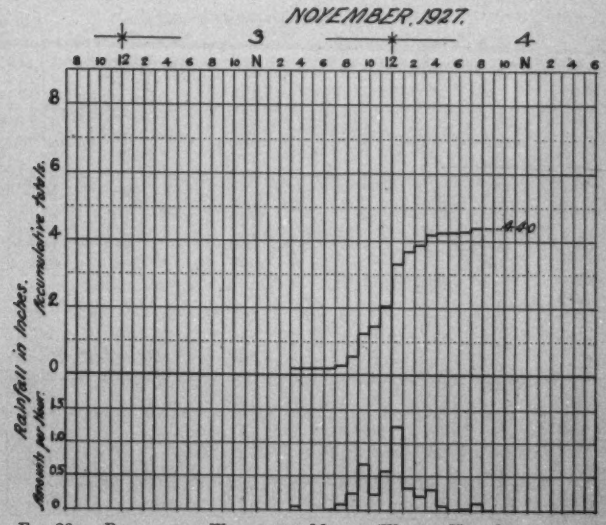


FIG. 26. — RAINFALL AT WORCESTER, MASS. (WINTER HILL OBSERVATORY.)

with a maximum rate for 2 hours of 0.39 in. per hour. At Northfield, Vt., rain fell for a period of 9 hours at 0.44 in. per hour with a maximum rate of 0.62 in. per hour. At Searsburg, Vt., rain fell for 22 hours at a rate of 0.29 in. per hour with a maximum rate of 0.59 in. per hour. At Somerset, Vt., the rate per hour equalled that at Northfield which was 0.44 in., but at Somerset the rainfall at that rate was continuous for 12 hours with a maximum rate for 2 hours of 0.66 in. per hour. At the sewage disposal works at Worcester, Mass., the average rate for 5 hours during the height of the storm was 0.90 in. per hour with a maximum hourly precipitation of 1.42 in. These records are selected at random and possibly rainfalls of greater intensity occurred at some points other than are mentioned here. It is evident that in a large section of Vermont the rainfall nearly equalled half an inch an hour for many consecutive hours, bringing upon the ground an immense quantity of water which the channels of the streams were utterly unable to remove. So far as the records show, the rate of rainfall in the Blackstone valley and in adjacent territory was even more excessive than elsewhere.

The character of the soil and the contour of the region in which this storm occurred favored a very rapid run-off into the streams. The maximum precipitation in the major storm area followed in a general way the main ridges of the Green Mountains in Vermont and Massachusetts. This region is a rugged mountainous country with steep slopes having for the most part a hardpan and clayey soil, though large areas are rocky and nearly impervious to water. In the eastern area in the watershed of the Blackstone River and along the boundary between Connecticut and Rhode Island the country is hilly and rolling with generally a clayey or hardpan sub-soil with few areas capable of absorbing water rapidly. Thus in the area affected by the storm the slope and contour of the ground and character of the soil were favorable to a very rapid run-off, especially in Vermont and western Massachusetts.

The condition of the ground and of the streams and ponds at the time the storm occurred no doubt aided in the destructiveness of the freshet that followed. The winter and spring of the year 1927, that is, the months from January to June, inclusive, were unusually dry. The average rainfall at stations in Vermont and western Massachusetts amounted to only about 72 per cent. of the normal for that period of the year. There have probably been only 4 or 5 years in the last half century in which the precipitation was so small within that period. Following the month of June there was a marked change and the rainfall in the summer and fall was high. The average rainfall at several of the higher stations in Vermont for the months from July to October, inclusive, was 16.56 in., while the normal is about 14.70 in. Far greater excesses obtained in central and western Massachusetts and in Connecticut. The average rainfall from July to October, 1927, inclusive, at the highest stations in western Massachusetts was 20.96, while the normal for those stations is 15.91. The

average rainfall for the month of October at a number of the higher stations in Vermont amounted to about 5.99 in., while the normal is about 3.35 in. In western Massachusetts the rainfall for October was 7.13 in., while the normal for the same stations is 3.58 in.

In the Blackstone valley area the rainfall for the four months previous to the storm amounted to 21.16 in., while the normal is 14.43. In the month of October the precipitation exceeded the normal in that region by about 2.45 in.

The following table shows the rainfall at the various stations during the period July to October, inclusive, 1927.

TABLE 2.

RAINFALL IN THE VICINITY OF FLOODED AREAS FOR THE PERIOD JULY–OCTOBER, 1927.

GAGE LOCATION.	1927.				TOTAL.	NORMAL.				TOTAL.
	Jul.	Aug.	Sep.	Oct.		Jul.	Aug.	Sep.	Oct.	
Northfield, Vt.	3.40	5.92	1.57	5.64	16.53	3.70	3.93	2.76	2.48	12.87
Woodstock, Vt.	4.51	3.24	1.40	5.45	14.60	3.91	3.39	3.46	3.00	13.76
Somerset, Vt.	4.06	4.86	2.75	6.87	18.54	4.60	4.31	4.01	4.56	17.48
Average				5.99	16.56				3.35	14.70
Savoy, Mass.	9.71	3.59	1.01	6.08	20.39	5.25	4.17	3.93	3.78	17.13
Plainfield, Mass.	4.37	3.43	2.36	7.15	17.31	4.62	3.52	4.59	3.74	16.47
Worthington, Mass.	5.33	4.73	2.55	6.87	19.48	4.09	3.72	4.27	3.87	15.95
Chester, Mass.	6.36	6.86	2.49	8.14	23.85	3.95	3.49	3.61	2.94	13.99
Otis, Mass.	6.48	7.88	2.00	7.40	23.76	4.60	4.29	3.56	3.56	16.01
Average				7.13	20.96				3.58	15.91
Wachusett Water Shed	5.94	9.48	3.51	5.02	23.95	4.15	4.09	3.62	3.26	15.12
Worcester, Mass.	5.23	8.70	3.41	5.50	22.84	3.57	3.38	3.35	2.88	13.18
Northbridge, Mass.	3.18	7.45	2.94	6.59	20.16	3.79	4.21	3.39	3.69	15.08
Webster, Mass.	3.06	6.66	2.15	5.80	17.67	3.75	3.81	3.49	3.29	14.34
Average				5.73	21.16				3.28	14.43

In consequence of these conditions the ground preceding the storm was thoroughly saturated, and streams and ponds were full to overflowing, except in the case of a few storage reservoirs having small watersheds in proportion to their capacity which happened to be drawn to a low level before the heavy rain set in early in the summer. These conditions were undoubtedly a main factor in the destructiveness of the storm.

It is of great interest to compare the effect of the excessive rainfall in this storm with the conditions which followed other similar storms in past years. Omitting intense local storms of the thunderstorm type there are fairly good records of rainfalls in the past 50 to 60 years in which the maximum precipitation exceeded 8 in. over a considerable area.

A storm of this type occurred in southern New England on October 12

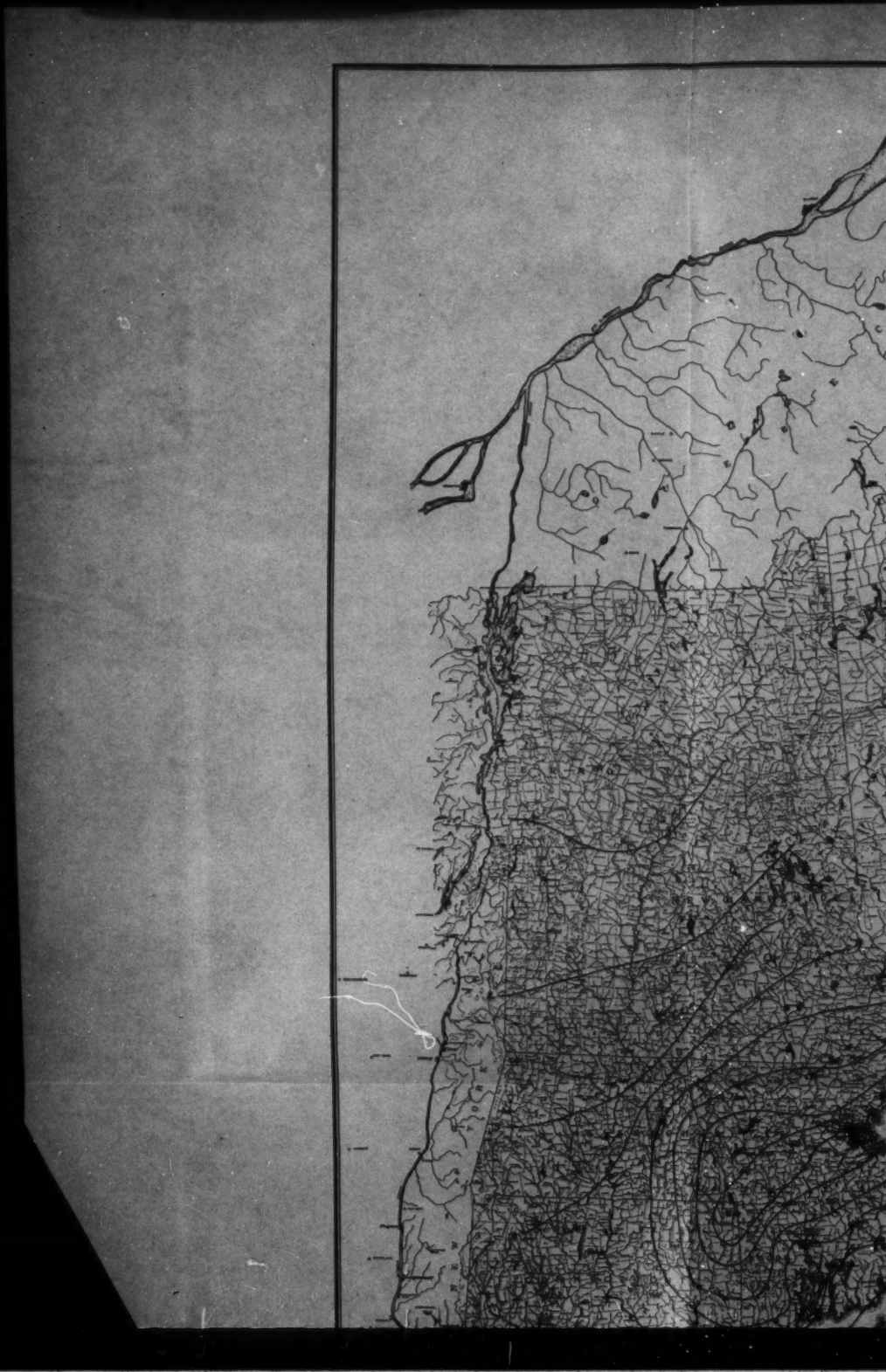


PLATE II.
N. E. W. W. ASSOCIATION.
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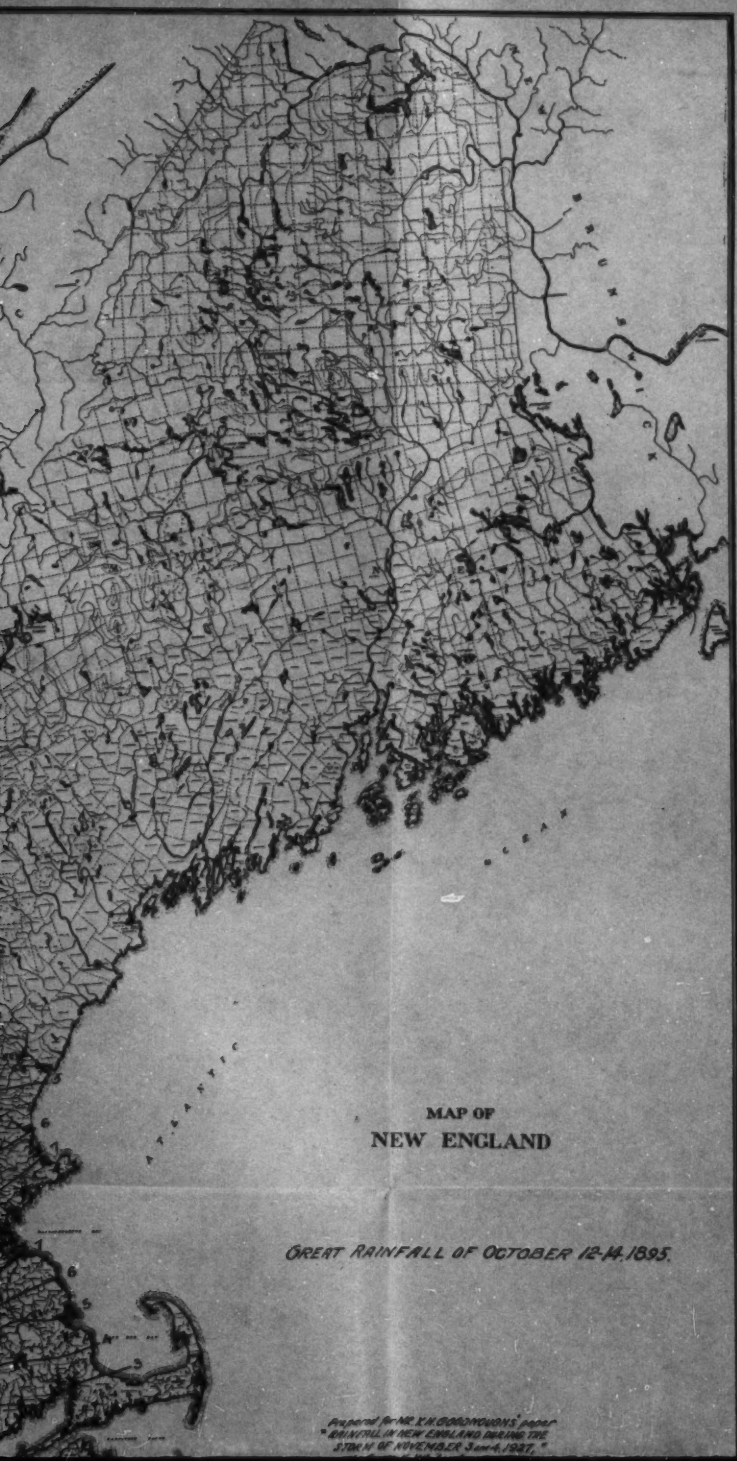
GOODNOUGH ON
RAINFALL IN STORM OF
NOVEMBER, 1927.

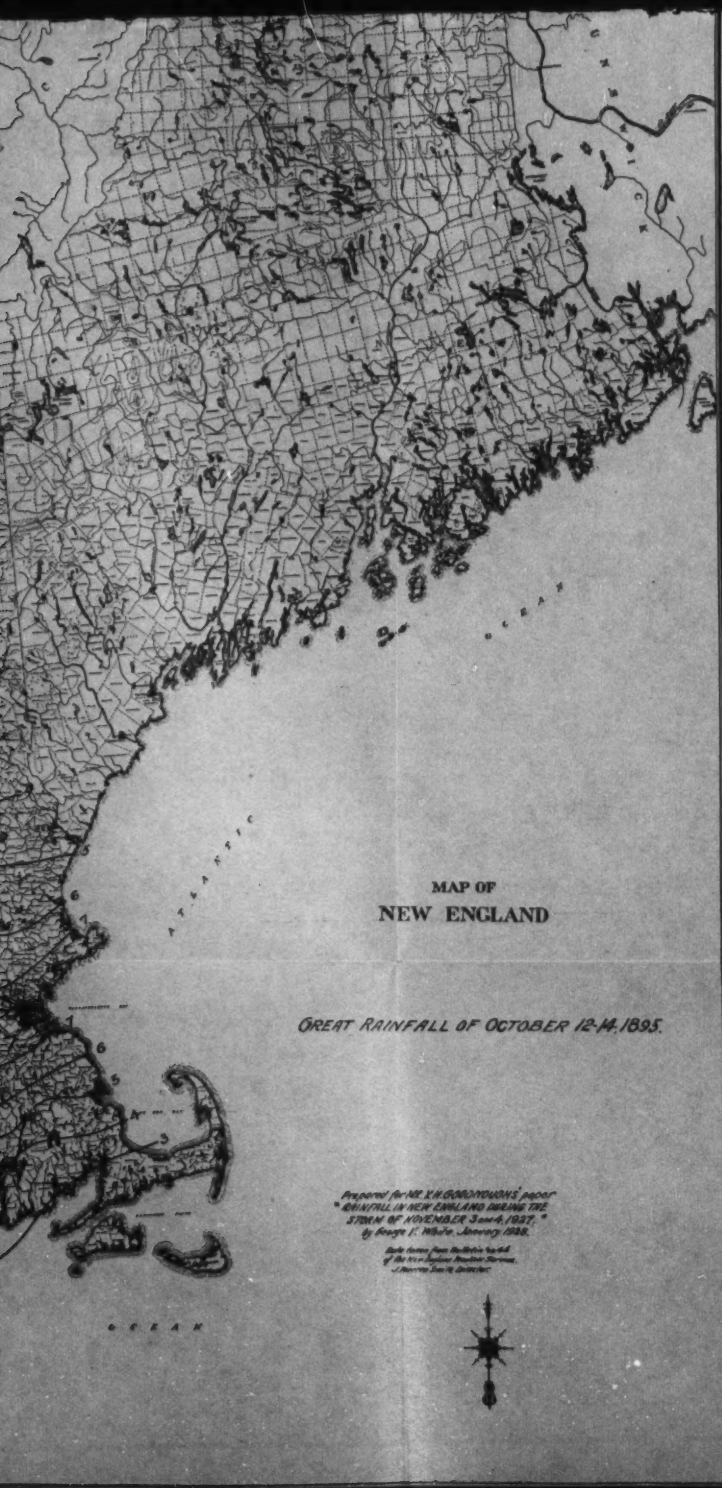


MAP OF
NEW ENGLAND

GREAT RAINFALL OF OCTOBER 12-14, 1895.

Prepared for Mr. X. H. GOODNOUGH'S paper
"RAINFALL IN NEW ENGLAND DURING THE
STORM OF NOVEMBER 3 and 4, 1927."

3
ATLANTIC


MAP OF
NEW ENGLAND
GREAT RAINFALL OF OCTOBER 12-14, 1895.
Prepared for Mr. X. H. GOODYOUGHS' paper
"RAINFALL IN NEW ENGLAND DURING THE
STORM OF NOVEMBER 3 and 4, 1927."
by George F. White, January 1928.
ATLANTIC
OCEAN
OCEAN

to 14, 1895, in which the rainfall exceeded 8 in. over an area of some 590 sq. miles, or about 40 per cent. of the area in Vermont in which there was a precipitation of over 8 in. in the recent storm. The storm of 1895 began in southwestern New England at midnight on October 11 and in the northwestern district early on the 12th. In eastern Massachusetts it began about 2 P.M. and in southeastern Maine later in the afternoon on the 12th. In eastern Massachusetts the rainfall ended by 4 A.M. on the 14th and in northern New England before midnight on the 13th.

The heaviest rainfall in this storm occurred in a section of country from North Grosvenordale, in northeastern Connecticut, to Waltham, Mass., covering much the same area as the smaller of the two storms of November, 1927. The area of excessive precipitation, however, extended to the east as far as the seacoast at Boston, the easterly part of this area lying mostly in a comparatively flat country in the watersheds of the Charles and Neponset rivers.

This storm occurred soon after the end of the summer season, some 23 days earlier in the autumn than the storm of 1927, and followed a period of less than average rainfall for that season of the year. Records kept by the late Desmond FitzGerald show that at Chestnut Hill the storm lasted from 1.30 P.M. on the 12th to 4.15 A.M. on the 14th, a period of about 38½ hours. Thus the storm appears to have been of about the same duration as that of 1927.

The year 1894 was one of the driest in New England for many years and the rainfall in the winter and early spring months of 1895 from January to April, inclusive, was much less than the average. The rainfall for the 5 months preceding the month of October, 1895, in which the storm occurred, was about 20 per cent. less than the average. For a period of 55 days preceding the storm, however, that is, from August 18 until October 12, the total precipitation in the area covered by the storm amounted to only 3.27 in., while the normal rainfall for that period of the year is about 6.58 in., so that the rainfall had been only about half the usual amount for the 55 days of the drier part of the year just before the storm occurred.

With regard to the rate of precipitation in this storm, satisfactory data are not available, but it is probable that the maximum rates did not vary greatly from those which occurred in areas of similar rainfall in the storm of 1927.

The effects of this storm were slight when compared with the destruction wrought by the storm of 1927. The excessive precipitation produced no serious freshets even in the area of greatest rainfall and no marked damage resulted at any point. The streams were filled but only those low grounds were flooded which are commonly inundated at times of high flow in practically every year.

The following table gives the areas in which the greatest precipitation occurred. The limits of these areas are shown in Plate II.

TABLE 3.

AREAS FLOODED BY STORM OF OCTOBER 12–14, 1895.

Over 8 inches.	*Square Miles.*
In Massachusetts	400
In Rhode Island	70
In Connecticut	120
	590
Over 7 inches.	
In Massachusetts	1 630
In Rhode Island	165
In Connecticut	250
	2 045
Over 6 inches.	
In Massachusetts	3 030
In Rhode Island	435
In Connecticut	605
	4 070
Over 5 inches.	
In Massachusetts	4 070
In Rhode Island	710
In Connecticut	1 020
In New Hampshire	540
	6 340

On February 10–14, 1886, occurred a rain storm which created the greatest freshets that had been recorded in southeastern New England for the last 40 years, previous to the storm of 1927. The conditions in this storm were vastly different from those which obtained either in the storm of 1927 or in that of 1895. The storm of 1886 is quite fully described in a paper by Winslow Upton, at that time director of the New England Meteorological Society, which is printed in *Science*, March 19, 1886, p. 163. The extent of territory covered by the rainfall is given by Mr. Upton as follows:

Amount of Rainfall.	*Area in Square Miles.*
Over 8 inches	750
Between 7 and 8 inches	750
Between 6 and 7 inches	1 500
Between 5 and 6 inches	1 850
Between 4 and 5 inches	2 750

This storm passed northeasterly diagonally across the State of Rhode Island from the Connecticut boundary and across the State of Massachusetts to the sea south of Boston, the heaviest precipitation occurring in the neighborhood of Providence. The territory affected was a little farther

PLATE III.
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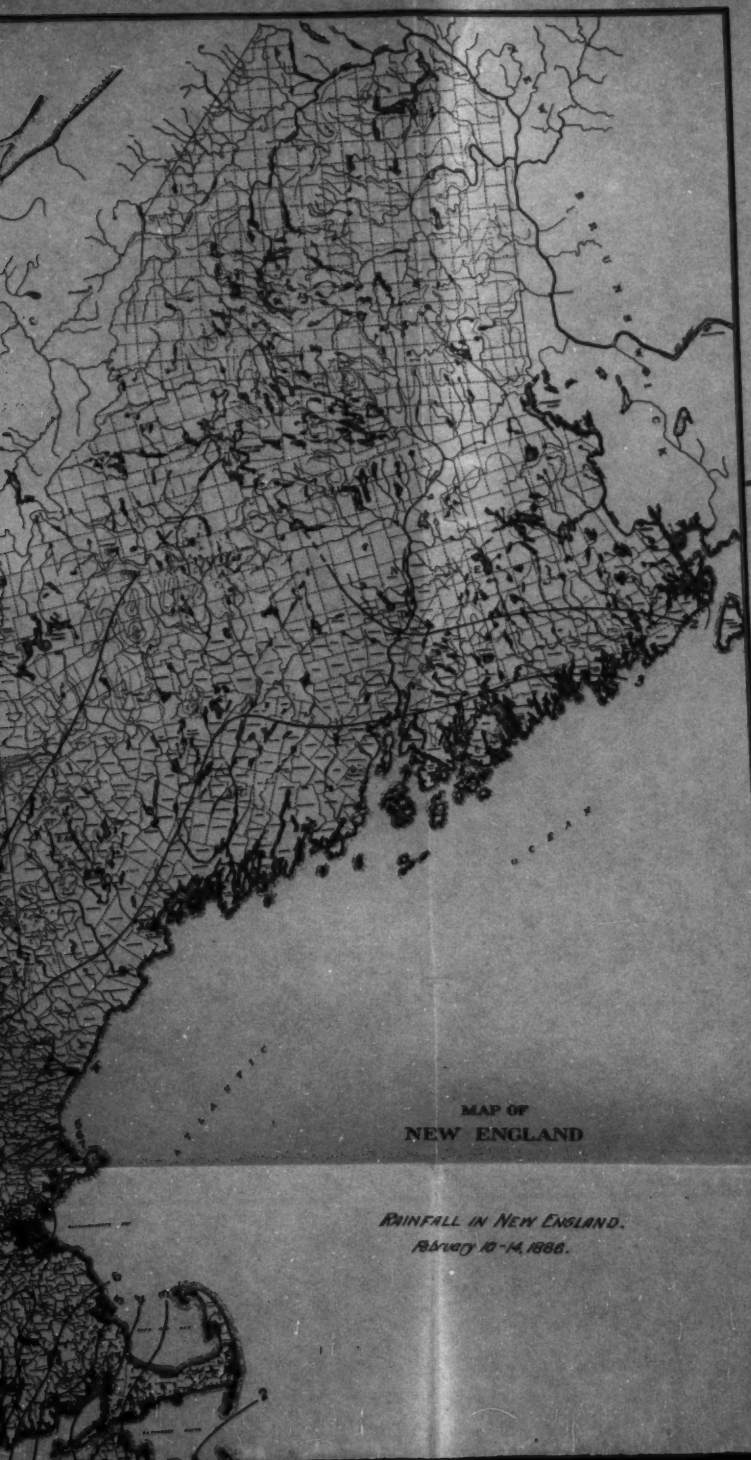
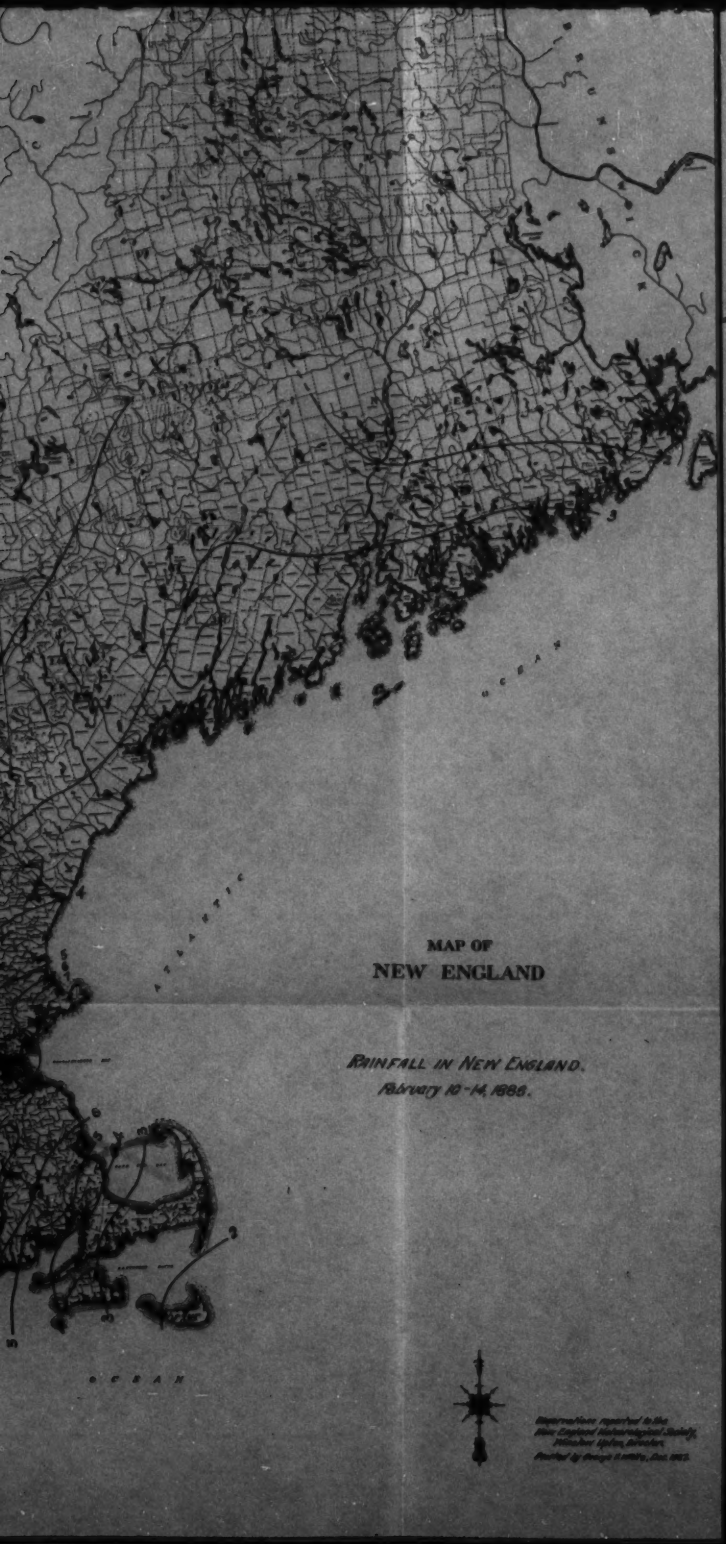
RAINFALL IN STORM OF
NOVEMBER, 1927.



MAP OF
NEW ENGLAND

RAINFALL IN NEW ENGLAND.
FEBRUARY 10-14, 1886.


MAP OF
NEW ENGLAND
RAINFALL IN NEW ENGLAND.
February 10-14, 1888.
ATLANTIC
OCEAN
OCEAN
Observations reported to the
New England Meteorological Society,
Winslow Upton, Director.
Printed by George H. White, Dec. 1887.

to the southeast than in the storm of 1895 or in the secondary storm in November, 1927. Plate III shows the lines of equal rainfall in this storm.

The time of beginning and ending of the storm of 1886 at several stations along its course is given by Mr. Upton as shown in the following summary:

Stations.	*Time of Beginning.*	*Time of Ending.*
New York	10th, 10.30 A.M.	13th, Noon
New London	11th, 6.00 A.M.	13th, 4.20 P.M.
Providence	11th, 1.00 A.M.	13th, 11.30 P.M.
Boston	11th, 7.45 A.M.	13th, 2.45 P.M.
Newburyport	10th, 5.30 P.M.	13th, 10.30 P.M.

The maximum rainfall in 24 hours at several stations during this storm is given as follows:

New York	2.99 inches.
New London	6.66 inches.
Providence	5.65 inches.
Boston	4.45 inches.
Newburyport	3.30 inches.

At the time this great rain began the ground was deeply covered with snow, the depth of the latter, as estimated generally by observers at that time, probably amounting to about 2 in. of rainfall. At the beginning the temperature was rather low and much of the rain was absorbed and held in suspension by the snow, comparatively little running off into the streams during the 11th and early part of the 12th. The temperature remained very nearly stationary during the 11th and the 12th, at a few degrees above the freezing point, but rose on the night of the 12th and the morning of the 13th to above 50° F., and it was at the time of this rise in temperature that the bulk of the precipitation occurred.

The effect of these conditions was to bring practically the entire quantity of snow on the ground, together with the bulk of the rainfall, into the streams within a comparatively few hours, producing the greatest freshets which apparently were ever recorded in southeastern New England up to that time. It produced an extraordinary flood in Stony Brook in the southern part of the city of Boston which inundated a thickly populated district, besides doing great damage in many other cities and towns in Rhode Island, Connecticut and eastern Massachusetts. The records of this flood have furnished a basis for the design of many conduits, channels and other engineering structures in this region since that time.

In 1878 a great freshet occurred in the Westfield River on December 10 following a precipitation of 3.18 in. of rain and snow. According to the accounts the ground was deeply frozen previous to the storm, which began in the form of snow, turning to rain when a depth of about one foot of snow had fallen. As the storm turned to rain the temperature rose very rapidly

and the snow melted very quickly which, together with the rain which it had absorbed, ran rapidly off into the river, producing a great freshet in that stream which inundated the town of Westfield. A report as to this storm and its effects, dated February, 1879, was made to the town of Westfield by the late Hiram F. Mills, A.M., C.E., who was engaged by a committee to report a plan for the permanent protection of the town from future floods.

The maximum rate of flow in the river resulting from this rainfall as estimated by Mr. Mills was 53 000 cu. ft. per sec. over a drainage area of 350 sq. miles, equal to about 51 cu. ft. per sec. per sq. mile.

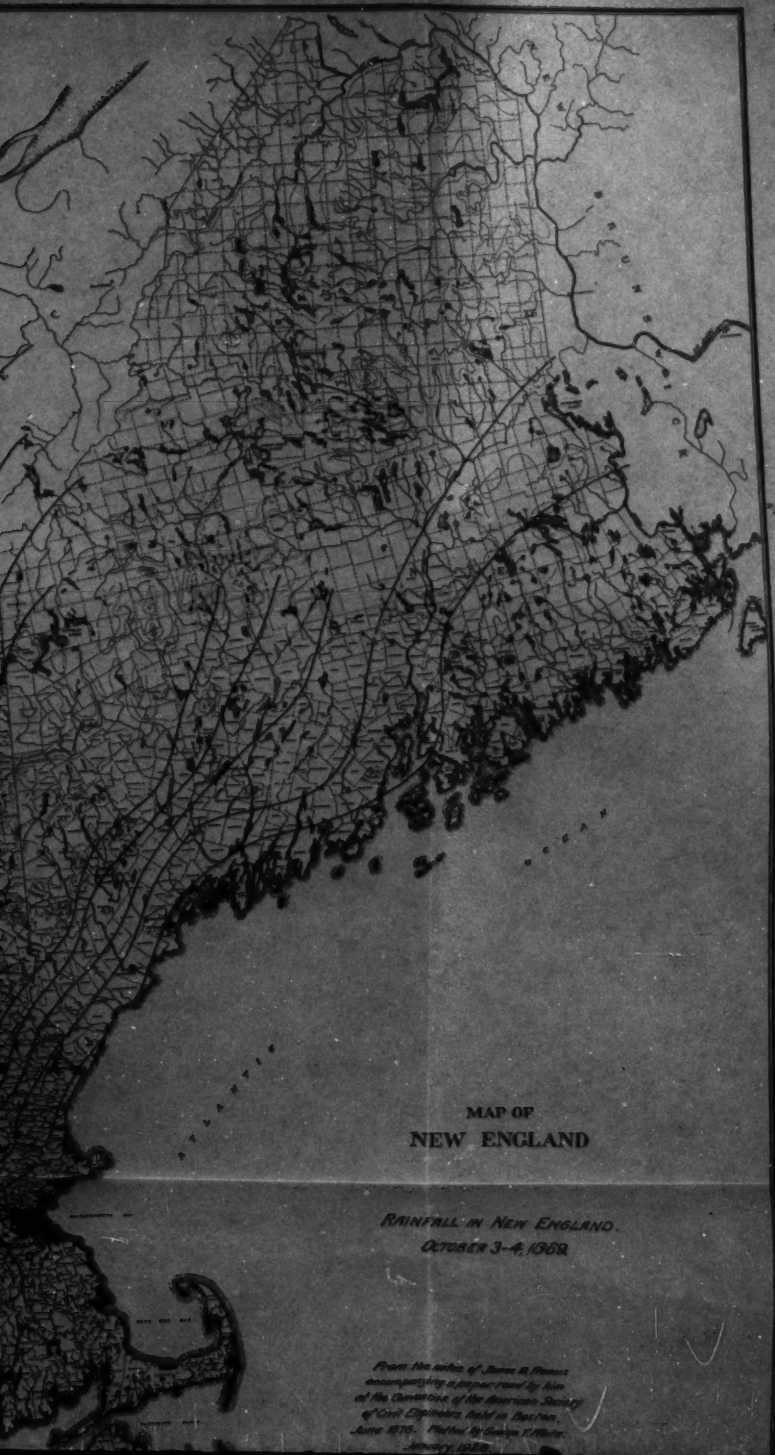
In 1874 a very considerable freshet occurred in eastern New England which resulted in a flow in the Sudbury River nearly equal to that of February, 1886. It was during this freshet that the Lynde Brook Reservoir of the Worcester water supply system was carried away.

One of the greatest freshets that ever occurred in New England resulted from the great rain of October 3 and 4, 1869. The storm is quite fully described by the late Mr. James B. Francis, the famous engineer, in a paper which was presented to the convention of the American Society of Civil Engineers held in Boston in June, 1878.

The storm was most intense in the Connecticut River valley but was very serious throughout central and northern New England, extending into Maine and beyond. The number of rainfall stations in existence in 1869 was comparatively small and it is very difficult to map this area accurately, but it is evident from the newspaper reports of the day that the freshet caused great destruction in a wide area of New England. At Concord, N. H., it began raining on the night of October 2, and up to daylight on October 5 over 2 in. had fallen. From that time until 4 P.M., that is in a period of about 10 hours, the newspapers state that there was a fall of 6 in., making the total precipitation at that point about 8 in. The newspapers complained that they had no exchanges except in eastern New England for many days. The maximum rainfall in this storm as shown by Mr. Francis's paper occurred at Canton, Conn., with a precipitation of 12.35 in.

The storm extended through the center of New England from western Connecticut, across the States of Massachusetts and New Hampshire, and into Maine. The rainfall exceeded 7 in. in an area of 3 901 sq. miles in Connecticut, southwestern Massachusetts, and adjacent parts of New York, and also exceeded 7 in. in an area of over 3 253 sq. miles in central New Hampshire and adjacent portions of Vermont and Massachusetts. The areas in which the rainfall exceeded certain specific amounts in each state are given in the following table, and the lines of equal rainfall are shown in Plate IV. The map covers a much larger area than is shown in Mr. Francis's paper and has been prepared by the use of available records of rainfall observations of that period.

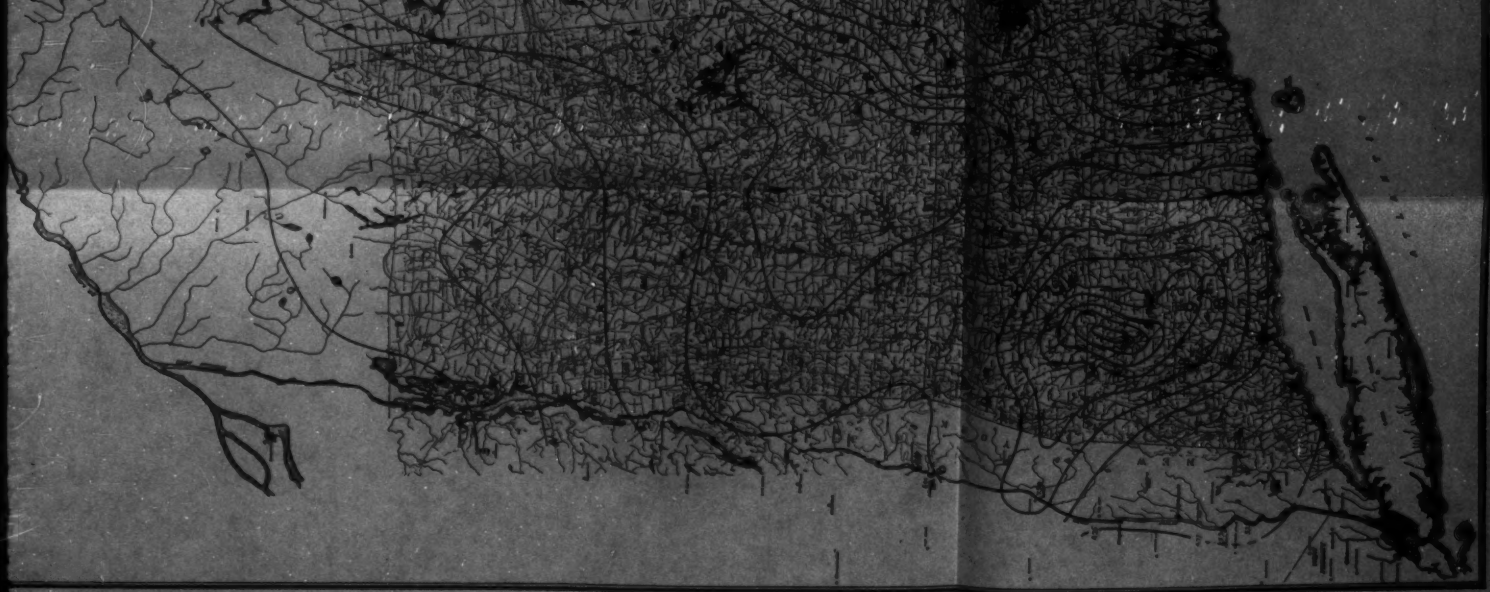
PLATE IV.
N. E. W. W. ASSOCIATION.
VOL. XLII.
GOODNOUGH ON
RAINFALL IN STORM OF
NOVEMBER, 1927.



MAP OF
NEW ENGLAND

RAINFALL IN NEW ENGLAND.
OCTOBER 3-4, 1869.

From the notes of James B. Francis
accompanying a paper read by him
at the Convention of the American Society
of Civil Engineers, held in Boston,
June 1878. Plotted by George Y. White.
January 1929.



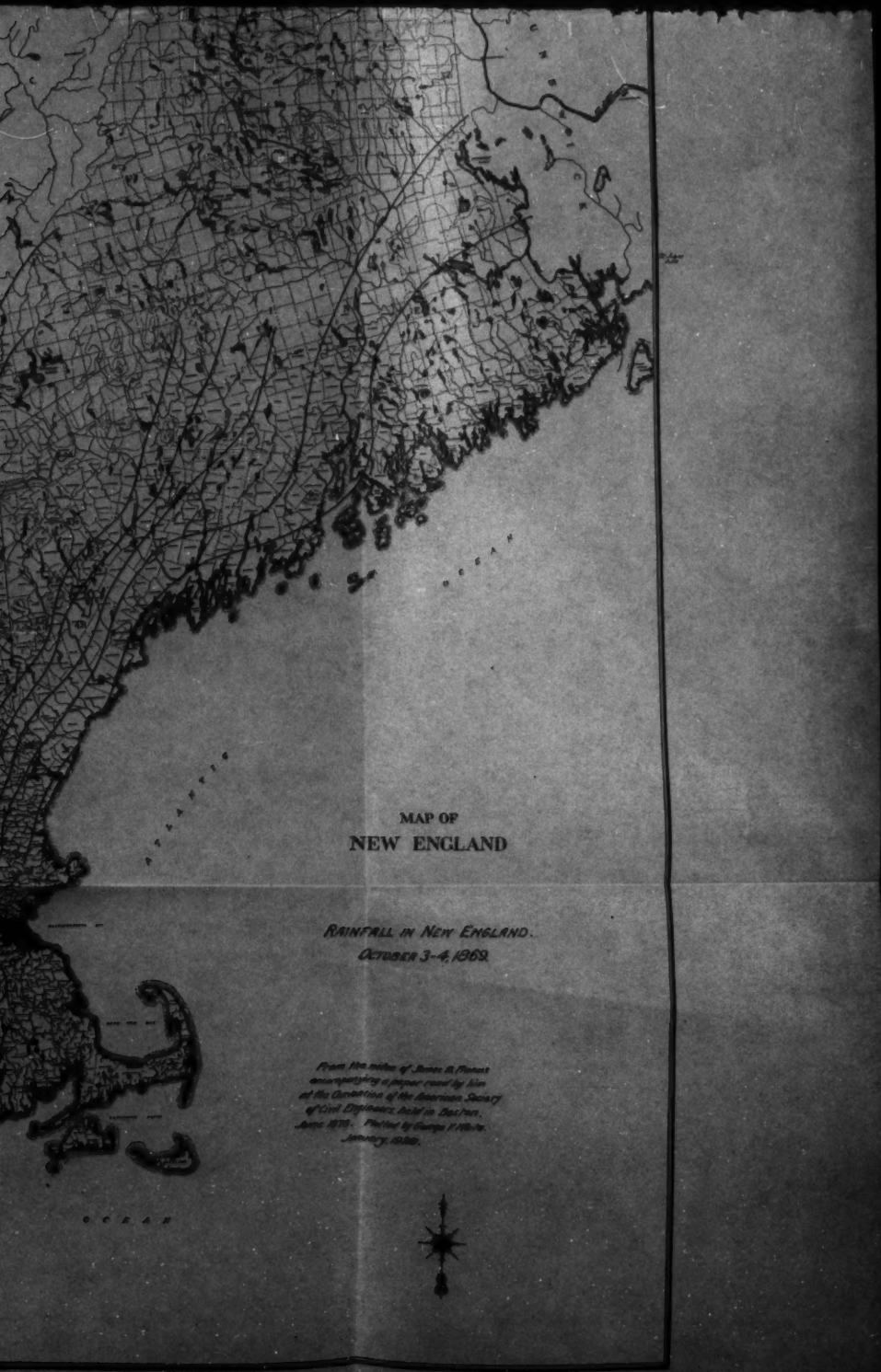

MAP OF
NEW ENGLAND
RAINFALL IN NEW ENGLAND.
OCTOBER 3-4, 1869.
From the notes of Jonas B. Francis accompanying a paper read by him at the Convention of the American Society of Civil Engineers, held in Boston, June 1870. Plotted by George F. Morse, January, 1880.
OCEAN
OCEAN

TABLE 4.

AREAS FLOODED BY STORM OF OCTOBER 3–4, 1869.

	Square Miles.
Over 12 inches.	
In Connecticut	40
Over 11 inches.	
In Connecticut and Massachusetts	255
Over 10 inches.	
In Connecticut and Massachusetts	370
Over 9 inches.	
In Connecticut	667
In Massachusetts	235
	902
Over 8 inches.	
In Connecticut	1 450
In Massachusetts	814
	2 264
Over 7 inches.	
In Connecticut	2 333
In Massachusetts (S. W. Section), and New York	1 568
In Massachusetts (Central)	333
In New Hampshire	2 508
In Vermont	412
	7 154
Over 6 inches.	
In Connecticut	3 314
In Massachusetts	3 304
In Vermont	1 804
In New Hampshire	5 150
	13 572

It is interesting, though somewhat futile, to attempt to study records of great storms occurring previous to 1869, since the number of rainfall stations diminishes rapidly going back through the years, and there are only two continuous records of rainfall in New England previous to 1825. There was unquestionably a great rain storm in August, 1826, which covered much of eastern New England as far north as the White Mountains, and the Willey House slide by which the Willey family was destroyed in the Crawford Notch in August, 1826, was no doubt a result of this storm. The records of rainfall at Boston and Lowell show a precipitation for the month of August, 1826 in excess of 9 in., and it is recorded that at Salem the total rainfall for the month was 14 in.

The New Bedford records for that month as hitherto printed show a total of 18.72 in., but a copy of the original rainfall record at New Bedford

made by Thomas R. Rodman, which has been supplied by the Blue Hill Meteorological Observatory with which the original record is now deposited, shows the following precipitation for the month of August, 1826.

August.	Amount (Inches).	August.	Amount (Inches).	August.	Amount (Inches).
1	.05	12	3.36†	23	...
2	...	13	2.50	24	1.33
3	...	14	.04	25	1.83
4	...	15	.01	26	.05
5	...	16	.03	27	...
6	...	17	...	28	...
7	1.74	18	.24	29	.05
8	.07	19	.02	30	...
9	...	20	...	31	...
10	...	21	.09		
11	4.83*	22	.40	Total	16.64

*Thunder and lightning and great rain.
†Much rain. Thunder and lightning in the night.

From this record it appears that there was a total precipitation of 10.69 in. from August 11 to 13 in that year and later 3.16 in. on August 24 and 25. The total for the month is 16.64, instead of 18.72 in. as previously given, the highest ever recorded for a single month at New Bedford and has been exceeded elsewhere in New England only at Lawrence in August, 1856, so far as known.

Finally, it seems worth while to refer to the great freshet in the Merrimack River in October, 1785. During that year a record of rainfall was kept at Andover by the Rev. Jonathan French from which it appears that the total rainfall in the month of September was 9.2 in., and in October, 10.1 in. The bulk of the rainfall in the month of October apparently occurred on the 20th, when it is said that 9 in. of water had fallen on the previous 3 days. It produced the greatest freshet in the Merrimack River that had been recorded in that stream previous to 1896, and the late Hiram F. Mills, for so many years in charge of the water powers at Lowell and Lawrence, once stated that he believed that the freshet of 1785 probably carried more water than that of 1896, the higher rise in the latter case probably being due to obstructions along the stream that did not exist in 1785.

A study of these storms indicates the great importance in estimating the effect of an excessive rainfall and giving due consideration to the conditions under which it may occur. A rainfall of 8 or 9 in. even though falling at a very rapid rate may produce comparatively little effect in a fairly level country at the end of a very dry period in summer or early fall compared with the effect that it may produce upon frozen ground or ground covered with snow or upon ground which has been thoroughly saturated by earlier storms. In the light of the recent observations it is most desirable that careful attention be given to the spillways of dams and reservoirs since the

greatest destruction of all occurs where a reservoir dam is carried away in a great rain storm. It may be of interest to add that during the recent freshet a reservoir constructed not long before under capable engineering advice nearly proved a victim to the excessive rainfall in that storm. The waste-way was constructed, it was thought, of ample size to prevent the water from overflowing the main part of the dam which, as it was constructed of earth, would be likely to go out if seriously eroded. At the height of the freshet the water rose for a very short time to a depth of 1.5 to 2 in. over the top of the earth portion of the dam, but a thick growth of grass rendered luxuriant by the frequent rains of the summer and fall prevented any serious erosion during the short period when this overflow occurred.

It is impossible to give a very definite estimate as to the frequency of the occurrence of such storms as that of November 3 and 4, 1927, within the limits of New England. We have evidence that they have occurred four times since 1869, that is on an average about once in 15 years, and there are quite reliable records of at least six such storms in the last 140 years, so that we may safely estimate that such storms may occur on an average as often as at least once in about 20 years.

The records of rainfall in New England cover so brief a period, however, that it is impossible to reach definite conclusions in this matter. The longest continuous rainfall record in New England is that at New Bedford, which has now been maintained for a period of 114 years. There is an available record at Boston for 109 years, at Lowell for 102 years, and at Waltham for 101 years, making four records that cover a period of a century. This period is comparatively so brief, however, that it is impossible to reach definite conclusions as to the frequency of great storms such as that of 1927, and the best estimate seems to indicate that they may occur in New England four or five times in a century. It is to be remembered, however, that there may have been greater freshets in the past which had less serious effect than the more recent ones because of the smaller population of the country at the time they occurred, and it is important to take into account in estimating the effect of future freshets the probable influence of structures along or over the streams in raising the level of the water or perhaps in retarding its flow. In any case, great as the recent freshet was, it is unsafe to assume that even the excessive precipitation in the recent storm will not at some time be exceeded.

Much has been said of the effect of storage reservoirs in reducing the height of water in freshets, and considerable popular misapprehension appears to exist on the effect of such reservoirs under such circumstances. If the rainfall happens to occur when the reservoirs have been drawn down the storage will of course help materially in reducing the intensity of the freshet, but when the reservoirs are full, or nearly so, the reduction would be comparatively small, unless the reservoir was of very large size in proportion to its watershed. There is no doubt that any pond or reservoir, even when full, reduces the maximum height of a freshet because of the

temporary storage which is made available by the rise of the water at such a time; but storage reservoirs that are to be used for the purpose of preventing or reducing freshets on a river to be most effective must be maintained with that purpose always in view. In order that they may be of value when the freshet occurs the storage capacity of such reservoirs, or at least that portion of it designed for relief from freshets, must be available at all times, otherwise their usefulness may be slight when the occasion to use them arises.

The records of rainfall upon which the map of the great storm of November, 1927, is based are given in the following tables. They include the records of the numerous rain gages of the Weather Bureau in all parts of New England and the adjacent sections of New York, the records of the Department of Public Health in Massachusetts, and the results of observations by various power companies, water departments and companies, and private observers.

Acknowledgments are due to the coöperation of the many observers who have supplied information given in the tables and especially to Mr. George A. Loveland, Meteorologist of the Boston Weather Bureau; Mr. H. B. Kinnison, District Engineer of the United States Geological Survey; Mr. J. Henry Weber of Clark University; Messrs. Arthur T. Safford and S. S. Kent, Chief Engineer and Assistant Engineer, respectively, Locks and Canals, Lowell; and to Messrs. Trotter & Cate, of Montreal. The work of compiling the records and the preparation of plans and diagrams have been carried out for the most part by Mr. Geo. V. White of the Department of Public Health.

Tables and diagrams are also appended showing the rate of precipitation at a number of places during this storm, the information having been furnished chiefly by the Weather Bureau, the New England Power Company and Mr. Safford.

TABLE 5.

RAINFALL IN NEW ENGLAND — GREAT STORM OF NOVEMBER 3 AND 4, 1927.

Maine.

CITIES AND TOWNS.	NOVEMBER.						TOTALS.	
	1	2	3	4	5	6	Nov. 2–5 Inc.	Nov. 2–4 Inc.
Aziscohos Dam	...	...	...	...	...	...	3.71	...
Bangor	...	...	...	.06	1.84	...	1.90	0.06
Bar Harbor	.02	...	...	1.95	...	...	1.95	1.95
Danforth	...	...	...	.80	1.55	...	2.35	0.80
Eastport	...	...	...	2.93	.21	...	3.14	2.93
Ellsworth	...	...	...	3.25	...	...	3.25	3.25
Eustis	.03	...	.64	2.81	.06	...	3.51	3.45
Farmington	...	...	.35	2.02	.00	.00	2.37	2.37
Fort Fairfield	.00	.00	.05	.04	1.99	.00	2.08	0.09
Fort Kent	...	...	.50	2.00	...	...	2.50	2.50
Gardiner	.02	...	.02	1.64	.02	.00	1.68	1.66
Greenville	...	...	.44	2.90	.04	...	3.38	3.34
Hiram	...	...	...	2.90	...	...	2.90	2.90
Houlton	...	...	.51	.25	1.83	T.	2.59	0.76
Jackman	...	.01	.41	1.62	.02	...	2.06	2.04
Lewiston	...	...	.06	1.38	T.	...	1.44	1.44
Lincoln	...	...	...	1.42	...	...	1.42	1.42
Machias	.03	...	...	1.40	...	...	1.40	1.40
Madison	...	...	.18	1.29	T.	...	1.47	1.47
Middle Dam	...	...	...	...	...	...	5.14	...
Millinocket	.00	.45	T.	3.73	.00	.00	4.18	4.18
Milo	...	...	.20	.93	.43	...	1.56	1.13
North Bridgton	...	...	.18	3.36	...	...	3.54	3.54
Old Town	.03	...	...	...	2.31	...	2.31	2.31
Portland	...	...	.01	.75	...	...	0.76	0.76
Presque Isle	.06	...	.06	.25	2.15	...	2.46	0.31
Ripogenus Dam	.00	.29	.26	2.76	.00	.00	3.31	3.31
Rockport (West)	...	...	...	...	1.41	...	1.41	1.41
Rumford	...	.05	.33	3.43	...	...	3.81	3.81
The Forks	.00	.02	.77	.79	1.85	.00	3.43	1.58
Upper Dam	...	...	...	...	...	...	4.52	...
Van Buren	.05	...	.15	.08	1.66	...	1.89	.23
Winslow	...	...	...	1.56	...	...	1.56	1.56
Woodland	...	...	.14	1.97	...	...	2.11	2.11

TABLE 5 (Continued).

RAINFALL IN NEW ENGLAND — GREAT STORM OF NOVEMBER 3 AND 4, 1927.

New Hampshire.

CITIES AND TOWNS.	NOVEMBER.						TOTALS.	
	1	2	3	4	5	6	Nov.2-5 Inc.	Nov.2-4 Inc.
Berlin	.00	.00	.63	4.25	.96	.00	5.84	4.88
Bethlehem (a)	...	...	...	2.40	...	...	3.65	...
Bethlehem	...	...	*...	4.50	...	...	4.50	4.50
Claremont	...	...	...	...	...	...	4.65	...
Concord	...	.03	1.37	2.73	...	T.	4.13	4.13
Dummer	...	...	.48	2.70	...	...	3.18	3.18
Durham	...	...	...	2.76	...	...	2.76	2.76
Errol	...	...	...	...	...	...	3.27	...
Fitzwilliam	...	1.19	2.24	.33	...	...	3.76	3.76
Franklin	...	...	.60	5.42	...	.03	6.02	6.02
Garvin's Falls	...	.09	4.10	...	...	...	4.19	4.19
Glencliff	.00	.00	.95	4.70	.25	.00	5.90	5.65
Gorham	...	...	.74	4.21	1.26	...	6.21	4.95
Gregg's Falls	...	T.	4.51	.09	.02	...	4.62	4.60
Hanover	.00	.00	3.81	2.55	.00	T.	6.36	6.36
Keene	...	*...	1.70	2.87	...	.01	4.57	4.57
Lakeport	...	...	.35	3.71	...	.06	4.06	4.06
Lancaster	...	...	.65	1.70	.25	.03	2.60	2.35
Lincoln	...	.60	3.97	.47	.02	...	5.06	5.04
Littleton	...	...	...	...	...	...	4.42	...
Manchester	...	.02	2.88	...	...	...	2.90	2.90
Merrymeeting Lake	...	...	.13	3.95	...	...	4.08	4.08
Nashua (c)	...	...	.03	4.04	.02	...	4.09	4.07
Nashua (d)	...	...	*...	3.92	...	...	3.92	3.92
North Stratford	.01	...	1.02	2.20	.50	...	3.72	3.22
Pittsburg (e)	...	.86	2.70	.65	...	...	4.21	4.21
Pittsburg (f)	...	1.23	3.02	.96	...	...	5.21	5.21
Plymouth	...	.40	4.65	.25	...	...	5.30	5.30
Plymouth (h)	...	T.	.94	5.19	...	...	6.13	6.13
Pontocook Dam	...	...	...	...	...	...	3.18	...
Twin Mountain	...	*...	*...	4.74	...	...	...	...
West Stewartstown	.10	...	.98	1.86	.26	T.	3.10	2.84
Woodsville	...	...	.96	4.16	.05	.03	5.17	5.12

(a) New England Power Co.
(c) Pennichuck Water Works.
(d) Jackson Mills.
(e) First Connecticut Lake.
(f) Second Connecticut Lake.
(h) Weather Bureau.
*Precipitation included in following measurement.

TABLE 5 (Continued).

RAINFALL IN NEW ENGLAND — GREAT STORM OF NOVEMBER 3 AND 4, 1927.

Vermont.

CITIES AND TOWNS.	NOVEMBER.						TOTALS.	
	1	2	3	4	5	6	Nov. 2–5 Inc.	Nov. 2–4 Inc.
Bellows Falls	.00	.00	.24	4.07	.18	.00	4.49	4.31
Bennington	...	...	*...	7.36	...	*...	7.36	7.36
Bloomfield	.01	...	1.02	2.20	.50	...	3.72	3.22
Brattleboro	...	.43	4.12	.12	.01	T.	4.68	4.67
Burlington	...	.52	3.75	1.35	T.	.15	5.62	5.62
Cavendish	...	...	4.92	3.04	.00	.01	7.96	7.96
Chelsea	...	...	2.83	4.52	...	...	7.35	7.35
Chittindon (a)	.00	1.65	6.60	.35	.00	.00	8.60	8.60
Cornwall	...	...	...	...	...	...	5.30	...
East Ryegate (b)	...	...	...	4.08	...	...	5.11	...
Enosburg Falls	.08	...	3.20	3.10	.05	.11	6.35	6.30
Garfield	...	...	4.07	3.87	...	.08	7.94	7.94
Middlebury	...	*...	2.00	2.80	...	...	4.80	4.80
Mollys Falls	...	...	...	...	...	...	9.14	...
Newfane	...	...	...	...	...	...	6.64	...
Northfield	...	...	6.17	2.46	.03	.08	8.66	8.63
Rutland (a)	...	1.90	6.12	.45	T.	.17	8.47	8.47
Searsburg (b)	.00	.00	.70	6.47	.03	.00	7.20	7.17
Searsburg Mt.	...	.00	.96	7.34	.17	...	8.47	8.30
Sherman	...	...	...	...	...	...	4.00	...
Silver Lake (a)	.00	.85	4.17	1.00	.49	.00	6.51	6.02
Somerset	.00	.00	.68	8.77	.20	.03	9.65	9.45
South Londonderry (b)	...	...	...	2.53	...	...	3.60	...
St. Johnsbury	.00	.00	1.00	5.39	.17	.02	6.56	6.39
Vernon (b)	.00	.00	.35	3.58	.18	.00	4.11	3.93
White River Junc. (b)	...	...	1.00	5.41	.18	.00	6.59	6.41
Whitingham (b)	.00	.00	.45	5.50	.06	.00	6.01	5.95
Wilder (b)	...	...	...	4.87	...	...	6.53	...
Woodstock	.00	.00	4.26	3.12	.00	...	7.38	7.38

*Precipitation included in following measurement.
(a) Vermont Hydro Electric Company.
(b) New England Power Company.

TABLE 5 (Continued).

RAINFALL IN NEW ENGLAND — GREAT STORM OF NOVEMBER 3 AND 4, 1927.

Massachusetts.

CITIES AND TOWNS.	NOVEMBER.						TOTALS.	
	1	2	3	4	5	6	Nov. 2–5 Inc.	Nov. 2–4 Inc.
Adams (Incomplete) (A)	...	...	5.10	...	...	...	5.49	5.49
Amherst	...	.30	3.43	1.90	T.	...	5.63	5.63
Ashby	...	...	...	4.80	.07	...	4.87	4.80
Ashland	...	...	* ...	4.82	...	T.	4.82	4.82
Athol	.00	1.00	4.83	.09	.00	.00	5.92	5.92
Athol (b)	...	1.13	4.05	.04	T.	...	5.22	5.22
Attleboro	...	T.	2.25	...	...	T.	2.25	2.25
Baldwinville	...	.42	3.62	.39	...	...	4.43	4.43
Barre	...	.23	4.32	...	...	...	4.55	4.55
Beverly (c)	...	...	1.70	.64	...	.14	2.34	2.34
Blue Hill Observatory	...	...	.04	2.12	...	T.	2.16	2.16
Bondsville (Palmer)	...	.15	3.31	T.	T.	.02	3.46	3.46
Boston (W. B.)	.00	.00	.44	1.37	.00	T.	1.81	1.81
Boylston	...	* ...	* ...	6.77	...	...	6.77	6.77
Brockton	...	...	2.27	.07	...	T.	2.34	2.34
Cambridge	...	...	0.80	1.30	...	...	2.10	2.10
Charlton	...	.39	3.04	.01	...	...	3.44	3.44
Chester	...	.55	6.95	...	...	.03	7.50	7.50
Chesterfield	...	.41	6.20	.03	.02	...	6.66	6.64
Chestnut Hill	...	T.	2.24	.07	...	.02	2.31	2.31
Clinton	...	* ...	* ...	6.76	...	...	6.76	6.76
Colrain	...	.27	4.02	.40	...	...	4.69	4.69
Concord	.00	.00	T.	2.84	.00	T.	2.84	2.84
Cummington	.00	.33	5.70	.48	.01	T.	6.52	6.51
Dalton	...	...	2.00	4.51	...	...	6.51	6.51
Dana	...	* ...	4.15	.18	...	...	4.33	4.33
Dana (North)	...	* ...	* ...	4.97	...	...	4.97	4.97
Edgartown	...	...	1.40	.30	...	...	1.70	1.70
Egremont	...	...	6.10	.06	...	.11	6.16	6.16
Fall River (W. B.)	...	...	.45	1.81	...	...	2.26	2.26
Fall River (W. W.)	T.	...	.55	1.11	...	...	1.66	1.66
Falmouth	...	...	1.86	.05	...	...	1.91	1.91
Fitchburg	...	.05	5.12	.14	...	...	5.31	5.31
Framingham	...	...	* ...	4.60	...	.01	4.60	4.60
Franklin	...	.01	2.67	...	.00	.00	2.68	2.68
Gardner	...	...	4.06	.03	...	...	4.09	4.09
Gloucester	...	...	...	2.18	...	...	2.18	2.18
Granville (West)	...	...	* ...	6.70	...	...	6.70	6.70
Greenfield	...	.57	4.47	.02	...	...	5.06	5.06
Greenwich	...	.50	3.80	.04	...	.05	4.34	4.34
Groton	...	.02	6.67	.01	...	.01	6.70	6.70
Hardwick	...	.23	4.50	.05	...	T.	4.78	4.78
Haverhill	...	...	T.	2.14	...	...	2.14	2.14
Haverhill (B)	...	T.	2.19	.09	...	.01	2.28	2.28
Heath	...	.23	4.73	.24	...	...	5.20	5.20
Hingham (Town)	...	...	1.79	.60	...	...	2.39	2.39
Holyoke (W. B.)	...	...	1.21	3.73	...	...	4.94	4.94
Holyoke (1)	...	...	1.66	3.46	...	...	5.12	5.12
Holyoke (2)	...	...	1.72	3.31	...	...	5.03	5.03
Holyoke (3)	...	.04	1.63	3.43	...	...	5.10	5.10
Housatonic	...	.70	4.93	.08	...	...	5.71	5.71
Hubbardston	.01	.21	3.93	.02	.02	.01	4.18	4.16
Hubbardston (C)	...	.22	3.20	.04	...	T.	3.46	3.46
Huntington	...	.31	5.93	.04	...	...	6.28	6.28
Hyannis	...	1.15	.10	...	...	...	1.25	1.25

TABLE 5 (Continued).

Massachusetts (continued).

Cities and Towns.	November.						Totals.	
	1	2	3	4	5	6	Nov.2–5 Inc.	Nov.2–4 Inc.
Ipswich	...	...	1.96	.54	...	...	2.50	2.50
Jefferson	...	...	* ...	4.27	...	...	4.27	4.27
Lakeville	* ...	* ...	* ...	2.91	* ...	...	2.91	2.91
Lawrence	.00	.00	T.	2.30	.00	T.	2.30	2.30
Lawrence (D)	...	...	1.80	.18	...	.06	1.98	1.98
Leominster	.00	.00	.27	4.89	.00	.02	5.16	5.16
Lincoln (a)	...	...	2.17	T.	...	.02	2.17	2.17
Littleton	...	T.	6.32	T.	...	T.	6.32	6.32
Lowell	...	...	* ...	3.28	...	...	3.28	3.28
Ludlow	...	.66	3.58	...	...	.03	4.24	4.24
Lynn	...	.01	1.74	.34	...	.03	2.09	2.09
Manchester	...	...	1.37	.41	...	...	1.78	1.78
Mansfield	...	...	2.03	.02	T.	...	2.05	2.05
Mansfield (W. B.)	...	T.	.18	1.92	...	...	2.10	2.10
Marlborough	...	...	...	7.48	.19	...	7.67	7.48
Middleborough	...	...	2.62	.08	...	T.	2.70	2.70
Middlefield	...	.64	6.28	.08	T.	.05	7.00	7.00
Middleton	...	.01	2.00	.24	...	.05	2.25	2.25
Milford	...	...	2.95	3.41	...	...	6.36	6.36
Millbury (A)	...	...	6.50	...	...	...	6.50	6.50
Millis	...	...	.03	2.48	...	.02	2.51	2.51
Monroe Bridge (A)	.00	.00	.42	5.78	.10	.00	6.30	6.20
Monson	...	.24	4.00	.01	...	.02	4.25	4.25
Nantucket	.00	.00	.03	1.52	.00	T.	1.55	1.55
Natick (P)	...	...	.01	2.57	...	.02	2.58	2.58
New Bedford (E)	...	T.	2.84	.07	...	...	2.91	2.91
New Bedford (W. B.)	...	...	.51	1.35	...	...	1.86	1.86
New Salem	...	...	...	6.05	.05	...	6.10	6.05
Newburyport	...	...	2.05	.30	...	...	2.35	2.35
Newton	...	...	2.11	.04	...	.04	2.15	2.15
North Adams (F)	...	...	.83	4.93	.28	...	6.04	5.76
North Adams (G)	...	...	.57	6.93	.24	...	7.74	7.50
North Andover	T.	...	.02	2.60	.49	.02	3.11	2.62
Northbridge	...	T.	* ...	7.74	...	T.	7.74	7.74
Norwood	...	.01	2.30	.02	...	T.	2.33	2.33
Otis	...	...	.55	5.85	.15	...	6.55	6.40
Otis (West)	...	.10	7.35	.08	...	.08	7.53	7.53
Peabody (West)	.00	.03	2.28	.24	...	.05	2.55	2.55
Pelham	...	1.32	2.93	.14	...	...	4.39	4.39
Pembroke	...	...	1.91	...	...	T.	1.91	1.91
Peru	...	.38	5.55	.08	...	...	6.01	6.01
Petersham	...	* ...	* ...	2.09	...	...	2.09	2.09
Pittsfield	.00	.00	.85	4.86	.00	.00	5.71	5.71
Plainfield	...	.70	6.09	.04	.01	.01	6.84	6.83
Plymouth	...	.01	1.52	.03	...	...	1.56	1.56
Prescott	...	.93	4.12	...	...	...	5.05	5.05
Princeton	...	...	* ...	4.00	...	...	4.00	4.00
Provincetown	.02	...	...	1.40	...	...	1.40	1.40
Reading	...	.02	2.00	.03	...	.04	2.05	2.05
Rochester	...	...	2.51	.13	...	...	2.64	2.64
Rockport	...	...	* ...	1.14	...	...	1.14	1.14
Rutland (North)	...	.20	3.96	...	.03	.02	4.19	4.16
Rutland (West)	...	...	* ...	3.35	...	...	3.35	3.35
Salem	.00	T.	2.43	.29	.00	.01	2.72	2.72
Savoy	...	1.97	2.34	1.43	...	.04	5.74	5.74
Shelburne Falls (A)	.00	.00	.26	3.54	.02	...	3.82	3.80
Shutesbury	...	1.12	3.91	0.30	...	...	5.33	5.33

TABLE 5 (Continued).

Massachusetts (continued).

Cities and Towns.	November.						Totals.	
	1	2	3	4	5	6	Nov. 2–5 Inc.	Nov. 2–4 Inc.
Southampton (H)	...	...	3.18	2.67	...	...	5.85	5.85
Southborough (I)	...	...	T.	5.31	...	.01	5.31	5.31
Southborough (J)	...	...	*...	8.39	...	T.	8.39	8.39
Southbridge	.00	.51	3.35	.01	.00	.01	3.87	3.87
Spot Pond	...	.01	1.85	.15	...	.04	2.01	2.01
Springfield (K)	.00	1.00	...	3.06	.00	.00	4.06	4.06
Springfield (L)	...	.06	3.08	1.14	...	...	4.28	4.28
Springfield (M)	...	.47	6.16	.15	.08	...	6.86	6.78
Springfield (N)	...	.80	5.61	.03	.02	...	6.46	6.44
Springfield (O)	...	1.32	2.87	...	...	...	4.19	4.19
State Farm (Bridgewater)	...	T.	.63	...	...	...	0.63	0.63
Sterling	...	...	*...	4.57	...	...	4.57	4.57
Stockbridge	.00	.86	4.95	.10	.01	.24	5.92	5.91
Taunton	...	...	*...	2.60	...	...	2.60	2.60
Turners Falls	.00	.49	3.48	.49	...	...	4.46	4.46
Walpole	...	...	T.	2.10	.08	T.	2.18	2.10
Waltham (W. W.)	...	.01	2.36	...	...	.02	2.37	2.37
Ware	...	.17	4.12	.08	.01	...	4.38	4.37
Ware (West)	...	*...	*...	4.15	...	...	4.15	4.15
Wareham	...	...	1.70	.04	...	T.	1.74	1.74
Wareham (East)	...	...	T.	1.62	.05	...	1.67	1.62
Warren	...	.19	3.75	.06	...	.01	4.00	4.00
Warwick	...	1.37	2.08	.36	T.	T.	3.81	3.81
Webster	...	.22	3.70	T.	...	T.	3.92	3.92
Wendell	...	...	1.81	4.10	.12	.05	6.03	5.91
West Brookfield	...	.39	3.72	.03	...	...	4.14	4.14
West Roxbury (Q)	...	T.	T.	2.05	.01	...	2.06	2.05
Westfield	...	.80	3.90	...	...	.02	4.70	4.70
Westhampton (R)	...	...	2.23	2.45	...	...	4.68	4.68
Westminster (S)	...	...	...	4.30	...	...	4.30	4.30
Westminster (T)	...	...	...	4.12	...	...	4.12	4.12
Weston (U)	...	...	.01	2.48	...	...	2.49	2.49
Williamsburg	...	.48	4.07	...	...	...	4.55	4.55
Williamstown	...	...	5.08	1.07	.01	...	6.16	6.15
Winchendon	...	.91	3.80	.33	...	...	5.04	5.04
Wollaston	...	...	1.98	.12	...	.01	5.15	5.15
Worcester (S. W.)	...	...	.06	5.09	...	...	2.10	2.10
Worcester (W. W.) (V)	...	...	.19	3.92	...	...	4.11	4.11
Worcester (W)	...	...	.15	4.30	...	...	4.45	4.45
Worcester (X)	...	...	.31	4.19	.09	.06	4.50	4.50
Worcester (Y)	...	...	.20	4.79	...	T.	5.08	4.99
Worcester (Z)	...	...	.10	4.59	...	...	4.69	4.69
Worthington	...	.50	6.00	.02	.02	.02	6.54	6.52
Wrentham	...	.10	2.60	...	...	...	2.70	2.70

(W. B.) Weather Bureau
(W.W.) Water Works.
(S.W.) Sewage Works.
(1) Whiting Street.
(2) Ashley Ponds.
(3) High Service.
(a) Hobbs Brook Reservoir.
(b) Fryville.
(c) Wenham Lake.
(A) New England Power Company.
(B) Kenoza Lake.
(C) Williamsville.
(D) Experiment Station.
(E) L. J. Hathaway.
(F) Broad Brook.
(G) Notch Brook.
(H) Fomer Reservoir.
(Z) Clark University.
(I) Sudbury Dam.
(J) Cordaville.
(K) United States Arsenal.
(L) City Hall.
(M) Borden Brook.
(N) West Parish Filters
(O) Provin Mountain Reservoir.
(P) Lake Cochituate.
(Q) Brookline Pumping Station.
(R) White Reservoir.
(S) Wachusett Lake.
(T) Meetinghouse Pond.
(U) Stony Brook Reservoir.
(V) Lynde Brook.
(W) Holden Reservoir.
(X) Kettle Brook.
(Y) Kendall Reservoir.
*Precipitation included in following measurement.

TABLE 5 (Continued).
RAINFALL IN NEW ENGLAND — GREAT STORM OF NOVEMBER 3 AND 4, 1927.
Rhode Island.

CITIES AND TOWNS.	NOVEMBER.						TOTALS.	
	1	2	3	4	5	6	Nov.2–5 Inc.	Nov.2–4 Inc.
Block Island	...	T.	2.87	...	...	...	2.87	2.87
Fiskeville (a)	T.	.00	.01	4.83	.01	...	4.85	4.84
Hopkins Mills (a)	T.	.00	.07	7.85	.02	.00	7.94	7.92
Kent (a)	.00	.00	.11	7.51	.09	.00	7.71	7.62
Kingston	...	...	.48	2.50	...	...	2.98	2.98
Newport	...	...	...	...	...	...	1.68	...
North Scituate (a)	.02	.00	.03	6.80	.00	.00	6.83	6.83
Pawtucket (1)	...	...	.06	2.69	...	...	2.75	2.75
Pawtucket (2)	...	...	T.	2.77	...	...	2.77	2.77
Pawtucket (3)	...	T.	T.	2.24	...	...	2.24	2.24
Providence (4)	...	...	*...	2.57	...	...	2.57	2.57
Providence (5)	...	...	*...	2.20	...	...	2.20	2.20
Providence (6)	...	...	*...	2.26	...	...	2.26	2.26
Providence (7)	...	...	*...	2.95	...	...	2.95	2.95
Providence (8)	T.	...	*...	1.97	...	...	1.97	1.97
Providence (W. B.)	T.	T.	.52	.74	...	T.	1.26	1.26
Rocky Hill (a)	.02	.00	.02	6.86	.02	.00	6.90	6.88
Wakefield	.00	.00	.15	2.26	...	...	2.41	2.41
Westerly	...	...	*...	9.12	...	...	9.12	9.12
Westerly (W. W.)	...	...	*...	9.37	...	...	9.37	9.37
Woonsocket	...	...	...	4.20	.18	...	4.38	4.20

(a) Providence Water Supply.
(1) Diamond Hill; (2) Pumping Station No. 3; (3) Masonic Building; (4) Sockanosset Reservoir; (5) Pettaconset Reservoir; (6) Precipitation Plant; (7) Fruit Hill Reservoir; (8) Hope Reservoir.
*Precipitation included in following measurement.

TABLE 5 (Continued).
RAINFALL IN NEW ENGLAND — GREAT STORM OF NOVEMBER 3 AND 4, 1927.
Connecticut.

CITIES AND TOWNS.	NOVEMBER.						TOTALS.	
	1	2	3	4	5	6	Nov.2–5 Inc.	Nov.2–4 Inc.
Bakersville (a)	...	...	*...	6.06	...	...	6.06	6.06
Barkhamsted (a)	...	...	*...	6.76	...	...	6.76	6.76
Bridgeport	.00	.01	3.09	0.73	.01	...	3.84	3.83
Colchester	...	*...	*...	4.21	.02	...	4.23	4.21
Hartford	...	.11	2.43	1.03	.01	...	3.58	3.57
Middletown	...	...	.39	3.29	...	...	3.68	3.68
Nepaug Dam (a)	...	...	*...	6.14	...	...	6.14	6.14
New Haven	...	.02	3.27	.51	.02	...	3.82	3.80
New London	...	...	.52	3.45	...	...	3.97	3.97
North Grosvenordale	...	...	.14	4.14	...	...	4.28	4.28
Norwalk	...	...	...	3.52	.05	...	3.57	3.52
Reservoir No. 4 (a)	...	*...	.71	3.27	...	...	3.98	3.98
Reservoir No. 6 (a)	...	*...	.56	3.46	.02	...	4.04	4.02
Storrs	...	.50	4.50	...	...	...	5.00	5.00
Thompsonville	...	...	.62	2.08	...	...	2.70	2.70
Waterbury	...	T.	2.91	2.21	.01	...	5.13	5.12
West Cornwall	.00	.03	2.45	2.85	.05	.04	5.38	5.33
West Hartland (a)	...	...	*...	6.64	...	...	6.64	6.64
West Hill (a)	...	...	*...	5.96	...	.16	5.96	5.96

(a) Hartford Water Works.
*Precipitation included in following measurement.

TABLE 5 (Continued).

RAINFALL IN NEW YORK — GREAT STORM OF NOVEMBER 3 AND 4, 1927.

CITIES AND TOWNS.	NOVEMBER.						TOTALS.	
	1	2	3	4	5	6	Nov.2–5 Inc.	Nov.2–4 Inc.
Albany	.00	.05	3.28	.53	.01	T.	3.87	3.86
Bedford Hills	...	.02	1.70	1.55	...	...	3.27	3.27
Carmel	...	...	.39	2.52	...	.06	2.91	2.91
Chazy	...	...	1.75	.73	...	.05	2.48	2.48
Cutchogue	.00	.19	1.91	1.40	.03	.00	3.53	3.50
Dannemora	.00	.00	.85	1.10	.20	.20	2.15	1.95
Flushing	...	...	.19	2.08	.03	.03	2.30	2.27
Glens Falls	.00	.00	.35	3.10	...	...	3.45	3.45
Harkness	...	T.	1.70	1.21	...	.02	2.91	2.91
Mechanicville	...	...	1.28	4.27	.12	.07	5.67	5.55
New York City	...	.02	1.68	.15	.07	...	1.92	1.85
Roslyn	...	...	2.05	1.15	.09	...	3.29	3.20
Scarsdale	...	.30	2.10	1.17	.10	...	3.67	3.57
Setauket	...	...	2.58	.53	...	...	3.11	3.11
Spier Falls	...	...	2.18	.88	.02	...	3.08	3.06
Wappingers Falls	.00	T.	3.32	1.43	.04	.00	4.79	4.75
West Point	.00	.96	4.14	.17	.07	.00	5.34	5.27
Yonkers	.00	.00	2.22	.38	.13	...	2.73	2.60

TABLE 5 (Concluded).

RAINFALL IN CANADA — GREAT STORM OF NOVEMBER 3 AND 4, 1927.

CITIES AND TOWNS.	NOVEMBER.						TOTALS.	
	1	2	3	4	5	6	Nov.2–5 Inc.	Nov.2–4 Inc.
Brome	...	...	1.45	2.02	.39	...	3.86	3.47
Drummondville	...	...	2.35	3.49	...	...	5.84	5.84
East Angus	...	...	.56	2.62	.30	...	3.48	3.18
Farnham	...	...	1.92	2.67	.02	.14	4.61	4.59
Lambton	.40	.55	.25	.40	...	...	1.20	1.20
Lennoxville	...	...	2.29	2.40	...	...	4.69	4.69
Megantic	...	*...	.58	1.75	...	...	2.33	2.33
Montreal	...	...	...	...	...	...	2.50	...
Nicolet	...	...	.53	4.50	...	...	5.03	5.03
Quebec	...	*...	...	...	...	...	2.02	2.02
Sherbrooke	...	.01	3.11	1.92	.01	...	5.05	5.04

*Precipitation included in following measurement.

TABLE 6.

HOURLY RAINFALL TAKEN FROM THE RECORDS OF RECORDING GAGES DURING THE GREAT STORM OF NOVEMBER 3 AND 4, 1927.

Date	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Albany, N. Y.																								
2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	T	.05	T
3	.01	.03	.03	.04	.25	.09	.16	.14	.25	.30	.18	.31	.27	.18	.12	.25	.08	.13	.12	.16	.05	T	.01	.12
4	.15	.05	.07	.05	.03	.03	.05	.05	T	T	.04	.01	T	...	...	...	...	...	...	...	...	...	...	...
Blue Hill Observatory.																								
3	...	...	...	...	T	T	T	...	...	...	...	...	...	...	...	...	...	...	.02	.02	.05	.11	.26	.40
4	.46	.17	.05	.04	.12	.19	.15	.07	.02	.01	.01	.01	...	...	...	...	...	...	...	...	...	...	...	...
Boston Mass. Weather Bureau.																								
3	...	T	...	...	T	T	...	...	...	...	...	...	...	...	...	...	...	...	...	T	.01	.01	.09	.33
4	.28	.15	.41	.09	.07	.11	.04	.15	.07	T	T	T	T	...	...	...	...	...	...	...	...	...	...	...
Brookline, Mass.																								
3	....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.01	...	.07	.20
4	.28	.16	.26	.10	.06	.10	.04	.04	.01	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
*Burlington, Conn. (Phelps Brook Dam).**																								
3	...	...	.16	.04	.18	.08	.02	.00	.01	.02	.01	.05	.38	.01	.05	.08	.28	.03	.23	.50	.29	.35	.34	.37
4	.20	.05	.27	.16	.42	.32	.06	.04	.05	.28	.18	...	...	...	...	...	...	...	...	...	...	...	...	...
Concord, N. H.																								
3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.12	.39	.80
4	.43	.62	.34	.66	.26	.31	.05	.04	.01	T	.01	T	...	...	...	...	...	...	...	...	...	...	...	...
Eastport, Maine.																								
4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.01	.46	.77	.51	.71	.32	.15
5	.12	.06	.03	T	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Hartford, Conn.																								
2	...	...	...	...	...	...	...	...	...	...	...	...	T	...	...	...	...	...	T	T	T	.01	T	.10
3	.01	.01	.03	.03	.06	.09	.01	T	T	T	T	.08	.10	.05	.01	.04	.10	.16	.44	.25	.27	.20	.26	.23
4	.25	.34	.08	.05	T	.14	.15	.02	...	T	T	...	...	...	...	...	...	...	...	...	...	...	...	...

TABLE 6 (*Continued*).

HOURLY RAINFALL TAKEN FROM THE RECORDS OF RECORDING GAGES DURING THE GREAT STORM OF NOVEMBER 3 AND 4, 1927.

Date	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Lowell, Mass.																								
3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.01	.05	.20	1.04
4	.53	.37	.67	.15	.07	.09	.07	.01	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Montreal, Que.																								
2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.02	.05	.04	.03	.04	.06	.12	.07	.05
3	.04	.07	.01	.03	.06	.02	.01	.00	.02	T	.07	.02	.03	.11	.06	.09	.08	.11	.12	.11	.02	.06	.16	.13
4	.09	.02	.03	.09	.06	.06	.06	.03	.02	.02	.04	.03	.02	T	.01	T	.01	...	...	...	...	...	...	...
New Haven, Conn.																								
3	T	.00	.03	.06	.02	.00	.05	.02	T	.00	T	.02	.08	.12	.24	.25	.30	.53	.27	.39	.06	.25	.30	.28
4	.22	.07	.06	.01	.13	.01	.01	...	...	T	T	...	T	...	...	...	...	...	...	...	...	...	...	...
New York, N. Y.																								
2	...	...	...	...	...	...	...	...	...	...	...	...	T	.01	...	.01	...	...	...	T	...	...	...	...
3	...	...	T	.04	.15	.02	T	T	.03	.09	.27	.03	.01	.15	.25	.19	.04	.27	.04	T	...	.05	.05	T
4	T	T	T	T	.01	.02	.02	.06	.03	.01	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Northfield, Vt.																								
2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.02	.20	.01
3	.03	.01	T	.04	.43	.29	.20	.14	.30	.15	.14	.45	.51	.54	.57	.62	.51	.31	.35	.38	.14	.35	.43	.24
4	.18	.16	.21	.11	.11	.10	.04	.02	.14	.15	.03	T	T	T	.02	T	...	...	...	...	...	...	...	...
Pawtucket, R. I.																								
3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.01	.04	.14	.31	.14	.33
4	.35	.30	.21	.09	.08	.08	.03	.13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Portland, Me.																								
3	...	...	T	.01	T	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	...	...	...	.02	.03	.25	.23	.03	.02	T	.02	.11	T	.04	...	...	...	...	...	...	...	...	...	...
Providence, R. I.																								
3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	T	.02	.08	.12	.07	.23
4	.12	.16	.16	.06	.07	.06	.03	.08	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Date	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Providence, R. I. (Hope Reservoir).																								
3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.05	.11	.10	.07
4	.12	.32	.20	.27	.05	.07	.10	.06	.04	.01	T	...	...	...	...	...	...	...	...	...	...	...	...	...
Springfield, Mass.																								
2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.00	.01	.03	.02
3	.04	.15	.06	.04	.07	.12	T	.00	T	.01	.00	.04	.24	.11	.06	.00	.02	.19	.29	.55	.28	.24	.28	.29
4	.18	.33	.11	.06	.02	.04	.35	.04	.00	.00	T	.01	...	...	...	...	...	...	...	...	...	...	...	...
*West Hartford, Conn. (West Hartford Filters).**																								
2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.03	.01	.11
3	.02	.04	.01	.10	.06	.03	.04	.00	.01	.00	.02	.09	.05	.06	.12	.14	.27	.35	.23	.30	.24	.10	.28	.22
4	.32	.31	.04	.04	.03	.12	.11	.01	.01	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Worcester, Mass. (Winter Hill Observatory).																								
2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.06	.02	T
3	T	...	...	...	...	...	.04	.02	...	...	...	...	...	...	...	.05	.00	.00	T	.09	.26	.68	.24	.59
4	1.26	.35	.21	.32	.07	.01	.02	.11	T	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Worcester, Mass. (Sewage Treatment Plant).																								
3	...	...	...	...	...	...	.06	...	...	...	...	...	...	...	.03	.01	.01	.01	T	.07	.39	.60	.88	1.42
4	1.19	.10	.23	.09	.01	T	.02	.03	.01	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

*Hartford Water Works.

TABLE 7.

RAINFALL INTENSITIES FOR VARIOUS PERIODS OF TIME FROM RECORDING GAGE RECORDS.

	Minutes.				Hours.		
	5	10	15	30	1	2	24
Albany, N. Y.	.07	...	.13	.22	.32	.63	3.49
Block Island	.16	...	.34	.57	.84	1.40	2.87
Blue Hill Observatory	.07	...	.17	.30	.51	1.07	2.16
Boston, Mass.	.09	...	.14	.27	.41	.58	1.81
Brookline, Mass.	.05	...	.11	.20	.33	.45	1.54*
Burlington, Vt.	.07	...	.15	.26	.46	.76	4.50
Concord, N. H.	.11	...	.38	.56	.85	1.37	4.04
Eastport, Me.	.17	...	.39	.52	.77	1.40	3.14
Hartford, Conn.	.11	...	.20	.33	.46	.63	3.22
Lowell, Mass.	.20	...	.44	.72	1.20	1.73	3.26*
Montreal, Que.	.03	...	.07	.12	.16	.29	1.64
Nantucket, Mass.	.14	...	.24	.39	.70	.99	1.55
New Haven, Conn.	.13	...	.28	.40	.59	.84	3.67
New York City	.16	...	.23	.27	.30	.47	1.68
Northfield, Vt.	.15	.19	.23	.42	.69	1.22	3.58
Pawtucket, R. I.	.06	...	.16	.26	.41	.66	2.24
Portland, Me.	.05	...	.08	.14	.25	.48	.75
Providence, R. I.	.06	...	.09	.17	.24	.37	1.26
Providence (Hope Reservoir)	.08	...	.13	.21	.32	.52	1.97*
Springfield	.09	...	.27	.41	.55	.83	3.08
Worcester (Winter Hill)	.27	...	.66	.73	1.26	1.87	4.92*
Worcester (Sewage Works)	.30	...	.61	1.04	1.65	2.60	5.07

INTENSITIES FOR 2 AND 24 CONSECUTIVE HOURS FROM POWER STATION RECORDS FURNISHED BY THE NEW ENGLAND POWER COMPANY.

Monroe (Bridge)	.78	5.78
Searsburg, Vt.	1.17	6.47
Shelburne Falls	.49	3.54
Somerset, Vt.	1.31	8.77
Vernon, Vt.	.80	3.58
Whitingham, Vt.	.81	5.14
Whitingham, Vt. (Davis Bridge Dam)	.71	5.50

*Twenty-four-hour period by stick measurement.

Discussion.

C. W. Mowry.* Aside from the direct property damage and the meteorological interest in rainfall and run-off, there were many other lessons that water-works engineers could learn from the storm of November 3–4, 1927.

Public water supplies in many towns were crippled temporarily when bridges supporting street mains were carried away, when mains crossing river beds were undermined or broken by flood-carried boulders, when wash-outs exposed and broke street mains, or when pumping stations were flooded. Water-department men worked feverishly day and night to repair the breaks and to restore water service for sanitary purposes and for fire protection after the interruptions, which varied from a few hours to a few weeks.

North Adams suffered seriously. Eight-inch, 12-in. and 16-in. mains crossing the river on bridges were wrecked, and 10-in. and 14-in. mains crossing on the bed of the river were broken. At Woonsocket, a 12-in. main crossing a bridge was deliberately broken by the Water Department for fear the bridge would be carried away and would break off the main back of the valve so that the water could not be shut off. By first shutting the valves and then breaking the pipe in between, this possibility was avoided. The experience, however, points out the desirability of locating gate valves well back from the bank and then anchoring the pipe securely by a concrete pier between the valve and river bank, as protection for the control valves.

In St. Johnsbury, Vt., an 8-in. and a 14-in. pipe laid on the bank of the Passumpsic River were broken. A 10-in. by-pass of steel spiral riveted pipe laid on the up-stream side of the bridge for use in case of the failure of the 14-in. pipe, was found worthless due to corrosion. At the present time, an 8-in. cast-iron pipe is being laid across the river on the ice. When all the lead joints are poured, it is the intention to cut an opening in the ice and lower the pipe to the bed of the river. To replace the 14-in. pipe, a special bridge is to be built. All of this work will take from two to three months.

These various experiences are also important from the fire-protection standpoint, because many valuable properties were left entirely without fire protection. Fortunately, no fires occurred, but the fire pumps which maintained pressure on the sprinklers throughout the interruption of public supplies, gave a good demonstration of the value of a secondary water supply for valuable properties.

*Assistant Manager Inspection Department, Factory Mutual Fire Insurance Companies.

PROCEEDINGS.

FEBRUARY MEETING.

CITY CLUB, BOSTON, MASS.
Wednesday, February 8, 1928.

Vice-President, ARTHUR D. WESTON, in the chair.

The Secretary announced that at the meeting of the Executive Committee on February 8, 1928, the following were elected to associate membership: Pratt & Cady Company, Inc. (reinstated); Antonio Gogavero, Peabody, Mass.

At the request of the Standardization Council of the American Water Works Association, this meeting was devoted to a discussion of "Water Works Practice," a manual published by the American Water Works Association. The matter of revising the manual was explained by Mr. B. C. Little, Secretary of the American Water Works Association, and papers upon particular phases of the matter were read as follows: "Allocation of the Use of Streams," Caleb M. Saville; "Flood Discharge," H. K. Barrows; "Watershed Pollution," E. Sherman Chase; "Treatment of Water," Robert Spurr Weston; "Pumping," F. W. Dean; "Management," Charles W. Sherman; "Industrial Wastes," Harry W. Clark; "Distribution," George H. Finneran; "Yield of Drainage Areas," Arthur D. Weston for X. H. Goodnough.

Messrs. Stephen H. Taylor and David A. Heffernan took part in the discussion.

(*Adjourned.*)

MARCH MEETING.

CITY CLUB, BOSTON, MASS.
Wednesday, March 14, 1928.

Vice-President, ARTHUR D. WESTON, in the chair.

THE CHAIRMAN. Since the last meeting of the Water Works Association, Mr. Frank E. Hall, a past president of the Association and one of the charter members, passed away in Worcester. Although it has not been our custom, I shall ask the members to rise in silent tribute to Mr. Hall's memory. (*Everybody stands.*)

I have an announcement to make which I think will be of special interest to water-works officials. During the present term of the Legislature Chapter 40 of the General Laws has been amended, upon petition of the Commissioner of Education, in such a way as to permit water-works officials

in this State to attend conventions and meetings and to have their expenses paid by the city governments.

This Act reads as follows:

"An Act Authorizing Municipal Appropriations For Certain Traveling* Expenses of Municipal Officers and Employees.

Be it enacted, etc., as follows:

Section five of chapter forty of the General Laws, as amended, is hereby further amended by adding after clause (33), inserted by chapter one hundred and sixteen of the acts of nineteen hundred and twenty-six, the following new clause:—

(34) For the necessary expenses of municipal officers and employees of any particular department incurred outside the commonwealth in securing information upon matters in which the city or town is interested or which may tend to improve the service in such department, if such appropriation is specified to be and is limited to such expenses incurred as aforesaid. Such expenses may also be incurred anywhere within the commonwealth and in such case shall be chargeable against any appropriation made for the ordinary maintenance of the department incurring the same.

Approved February 13, 1928."

Chapter 40 of the General Laws, Section 5, will now read in part as follows:

"Section 5. A town† may at any town meeting appropriate money for the following purposes:

(34) For the necessary expenses of municipal officers and employees of any particular department incurred outside the commonwealth in securing information upon matters in which the city or town is interested or which may tend to improve the service in such department, if such appropriation is specified to be and is limited to such expenses incurred as aforesaid. Such expenses may also be incurred anywhere within the commonwealth and in such case shall be chargeable against any appropriation made for the ordinary maintenance of the department incurring the same."

The Secretary announced that at the meeting of the Executive Committee on March 14, 1928, the following were elected to membership: Alfred S. Malcomson, Freeport, N. Y.; Edward G. Hughes, Watertown, Mass.; William E. Young, Baltic, Conn.; Frank H. Torrey, North Weymouth, Mass.; Lawrence M. Gentleman, Watertown, Mass.; Frank P. Morse, Salem, Mass.; Thomas P. McDermott, Lowell, Mass.; Byron Chapman Bussey, Pawtucket, R. I.; Lewis Henry Kunhardt, Melrose Highlands, Mass.; Joseph D. Guillemette, Pawtucket, R. I.; Guy H. Chase, Fitchburg, Mass.; Willard F. Rockwell, Pittsburgh, Pa.; Edward J. Guiney, Somerset, Mass.; Thomas Hargreaves, Somerset, Mass.; E. J. Looney, Belmont, Mass.

Associate: The Fairbanks Company, Valve Manufacturers, Boston.

The Secretary further announced that at the meeting of the Executive Committee, the Committee on Place of Holding the Annual Convention had made its report and that the report was adopted by the Executive Committee. The report was to the effect that the Association should hold

*And other.

†The terms "town" and "city" have the same meaning under the General Laws, and in the case of a city the appropriation should be passed by the City Council for expenses outside the limits of the Commonwealth.

its next annual convention about September 17, at Montreal, Canada. (*Applause.*)

The Secretary explained that word had been brought from the American Water Works Association to the effect that it was the desire of the Canadian Section and the New York Section of the American Water Works Association that the Convention of the NEW ENGLAND WATER WORKS ASSOCIATION be held at Montreal, or somewhere in the East, this year, because of the long distance of travel to San Francisco and other regular American Water Works Conventions. The Canadian, New York, Tri-State and Four-State Sections of the American Water Works Association might be expected, therefore, to join with the New ENGLAND WATER WORKS ASSOCIATION at its convention this year.

CHARLES W. SHERMAN. We have all read in the newspapers about the terrible disaster that has occurred in Los Angeles, apparently as the result of the failure of one of the dams of the Los Angeles Water Supply. The newspaper reports are not adequate for us to get any particulars except that the disaster is a terrible one and the loss of life very heavy.

I think it would be appropriate for the New England Water Works Association to pass a resolution to extend its sympathy to the water officials of the city of Los Angeles, and I so move.

(*The motion is duly seconded and carried.*)

The report of the Committee on Cross-Connections was submitted and read in part by Mr. Robert Spurr Weston. Mr. Warren J. Scott, Director, Bureau of Sanitary Engineering, Connecticut State Department of Health, explained the sanitary side of the question, and gave the methods employed by the Connecticut State Department of Health in inspecting cross-connections. Charles W. Mowry of the Inspection Bureau, Associated Factory Mutual Fire Insurance Companies, presented the insurance or fire-protection side of the matter. Mr. Stephen H. Taylor told of the methods of inspection of double check-valves at New Bedford.

The Committee, through its chairman, Mr. Robert Spurr Weston, moved that the recommendations of the Committee be adopted. (See the Report.)

After a discussion, participated in by Messrs. X. H. Goodnough, George F. Merrill, Stephen DeM. Gage, Patrick Gear, Frank A. Barbour, John O. Taber, Jr., H. V. Macksey, Thomas F. Lally, Henry A. Symonds, Caleb M. Saville, Edward V. French and M. N. Baker, the motion was withdrawn by Mr. Robert Spurr Weston, and on motion of Mr. George C. Brehm, as amended, duly seconded, it was VOTED that the consideration of the report of the Committee on Cross-Connections be postponed, that the report be printed in the June JOURNAL, and that a foreword be inserted under the title of the Committee Report, showing that the report was being published in advance of consideration by the Association and for the information of the whole membership.

(*Adjourned.*)

REPORT OF COMMITTEE ON CROSS-CONNECTIONS.

[This report is published in the JOURNAL in advance of consideration by the NEW ENGLAND WATER WORKS ASSOCIATION so that the membership may become acquainted with the subject matter of the report.]

[*Presented March 14, 1928.*]

Mr. President and Members of the New England Water Works Association: The undersigned, having been appointed by you members of a Committee on Cross-Connections, having held several meetings, and having collected many data, respectfully submit the following report:

Definitions. By a cross-connection is meant a connection between the distribution system of a public or private, potable water supply and a private or secondary, non-potable water supply.

One common example of a cross-connection is that between the public water supply of a municipality and the auxiliary fire-hydrant or sprinkler supply of a mill or factory,— the former sufficing for ordinary uses and the latter for fire fighting only. Another frequent case is where under ordinary conditions the public supply is taken for drinking purposes and for use in toilets and lavatories only,— water for all other purposes being taken from the secondary industrial supply. In a third common instance, water for various industrial processes, including boiler-feed water, as well as drinking water and water for toilets and lavatories, is taken from the municipal source, leaving the industrial source for private fire supply and miscellaneous industrial uses. For a more extended classification of cross-connections see Appendix A.

Connections are usually made through piping and gate-valves, with or without accompanying check-valves. Check-valves vary in type from simple, single, iron check-valves, with a swinging clapper, operating against an unfinished iron seat, to elaborate double, bronze, check-valves, like those devised and specified by the Associated Factory Mutual Fire Insurance Companies. The former are not precisely machined to prevent leakage, are usually rendered inaccessible by being buried in the ground, and are liable to rust so that the free movement of their clapper is obstructed. The latter are of excellent workmanship, are usually set in pits, or where they are accessible for inspection at all times, and are built of non-corroding bronze with rubber-on-bronze seats. This type of valve is equipped with gages and test cocks. (See accompanying figure.)

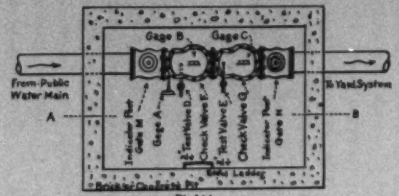
The Demand for Cross-Connections. The principal demand for the establishment of cross-connections comes from fire insurance companies and from property owners who desire two rather than one source of water supply in order that there may be additional protection to life and property. Opposition to cross-connections has come principally from the health and

NORMAL CONDITION OF VALVES

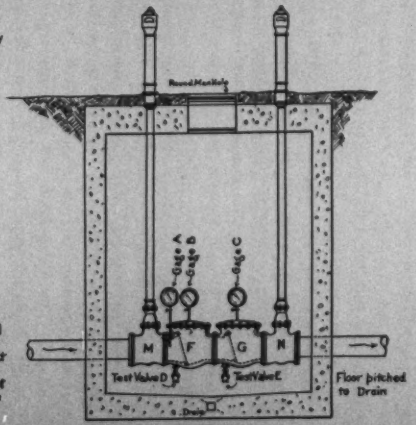
OPEN
Gates M-N

SHUT
Test Valves D-E

About once a year inspect check valves and thoroughly clean whole interior



PLAN



SECTION THROUGH A-B

Size of Pit etc will vary with different sizes of valves and local conditions but in general the Pit should be not smaller than about 4'-6" x 8'x 6' deep
Pit to be water tight where in wet soil and properly drained where in dry soil

METHOD OF TESTING

Open test valve D to blow out any sediment that may have accumulated in test valve or connecting pipe and then close.

Close gate M and open test valve D If pressure falls at gage A & pressure at gage B holds after decreasing slightly, check F is tight.

While test valve D remains open and pressure at gage A stands at zero, open test valve E. If pressure at gage B falls to zero and flow from test valve E ceases, check G is tight.

CAUTION - Immediately at close of test see that gates M and N are open. It is important that the protection be promptly restored.

FIRE SERVICE CONNECTION USING TWO CHECK VALVES - OF APPROVED TYPE -

CONNECTICUT STATE DEPARTMENT OF HEALTH

OCT 1926 FAAA.

Not to scale

water-works authorities, largely because numerous epidemics of disease have been traced to these connections.

Cross-Connections for Industrial Purposes and Fire Protection. The question of the practical importance of cross-connections for industrial use and fire protection was referred to a sub-committee which reported as follows:

Industrial Use. Many large industrial plants and public utilities require a constant supply of water for boiler feed, for cooling purposes and for various manufacturing processes. To insure continuous operation, some secondary standby supply, instantly available in emergency, must be provided.

It is usually prohibitive in cost to purchase public water for ordinary uses and at the same time to store a supply of potable water sufficiently large for probable emergencies. Some way of using both the public supply and a secondary supply when needed is a practical necessity.

Fire Protection. The automatic sprinkler has made it possible to concentrate with safety enormous values in industrial plants, mercantile buildings and warehouses. The manufacturers of the country have utilized this advantage to such an extent that adequate fire protection is now a necessity for the profitable continuance of their business. It is doubtful if the industrial development of this country could have been so extensive without the safeguarding influence of automatic sprinklers.

A good public water system is the very best primary supply for automatic sprinklers, and there is usually no practicable way of providing an alternative primary supply that is the equivalent of a good public water system. Even large elevated tanks storing water from the public supply and erected at great expense are necessarily of limited pressure and capacity. But municipal water supplies *alone* cannot be depended upon in all cases, for two reasons:

1. Fire will not wait in case the public water supply should happen to be out of service. If the tremendous advantages of automatic sprinklers in extinguishing fires *at the start* are to be realized, there must be pressure *always* on the sprinklers.

The Associated Factory Mutual Fire Insurance Companies have recorded about three hundred instances in which public water supplies have failed or been interrupted. In twelve of these instances fire broke out simultaneously with the interruption of the water supply.

2. Public water supplies are frequently *inadequate* in volume and pressure for the large number of automatic sprinklers and hose streams that might be needed to cope with a serious fire.

Therefore, whenever the value protected, or the fire or life hazard involved, is sufficiently great, a secondary supply is needed in order that automatic sprinklers shall control a fire at the start. The Labor Laws of New York State permit double the number of employees in buildings equipped with sprinkler systems.

It is usually impracticable at reasonable cost to provide a secondary

supply of potable water of sufficient capacity to assure a volume of water adequate for an emergency, such as an unusually severe fire or a conflagration. Secondary supplies of non-potable water, however, can be obtained in sufficient volume by utilizing open bodies of water, such as ponds and rivers. A cross-connection is at present the only practicable method of combining existing potable public water systems and available non-potable secondary supplies of large capacity, both automatically feeding into a common fire protective system capable of meeting the demands of sprinklers and hydrants during the progress of a fire. Such cross-connections, in order to function instantly when fire occurs, cannot be dependent upon manual operation, but must be automatic.

Cross-Connections and the Public Health. The matter of the relation between cross-connections and the public health was also referred to a subcommittee, and the following is a brief abstract of twenty-five instances on record where outbreaks of disease have been brought about by pollution of drinking-water supplies through cross-connections. Details of these occurrences are given in Appendix B.

In nineteen of these instances the cross-connection contained a single gate- or check-valve. It must be borne in mind that a gate-valve is not an automatic device and that it affords no protection unless closed. In three instances, protection against mixing of unsafe with safe water was afforded by two gate-valves or by a check-valve and a gate in series, and in one instance there were two gate-valves and a check-valve in series on the cross-connection. In one instance, it might be assumed from the wording of the published record that protection against pollution was afforded by two gate-valves and a double check-valve arranged in series, although this was not definitely stated. In another case this condition was definitely stated. It is also true that one of the double check-valves that failed was of inferior type and that one had not been inspected recently.

In addition to the appended list of recorded cases of sickness or death due to pollution entering drinking-water systems through cross-connections with unsafe water supplies, the Conference of State Sanitary Engineers and several sanitary authorities have listed a considerable number of cases where trouble was caused by the introduction of polluted water through leaks in emergency intakes or by similar causes. The report of your Committee, however, is limited to the effect of cross-connections, important as the other sources of danger may be.

Position of the Public Health Authorities. While from the broad economic standpoint it may be undesirable to run the risk of fire losses and, possibly, some losses of life by accident to firemen and industrial employees in order to avoid the hazard of sickness and death due to the existence of cross-connections, the saving of life rather than of money must always be the dominant motive for sanitary authorities. The following may be given as examples of the reactions of sanitary authorities to this danger.

The position of New Hampshire is as follows:

"As a historical preface, it can be stated that this matter has been receiving consideration by the New Hampshire Board of Health for more than a dozen years. Attempts at reform had their inception when, as a result of some bad conditions discovered, a legislative bill was introduced which sought to prohibit the existence of any connection on a public water supply through which polluted water might be introduced therein.

"The opposition at the time of the industrial interests was so intensely manifested and the impossibility of establishing a flat prohibition was so obvious that this department next proceeded to consider the special safety devices that were then available. Manufacturers were advised that the situation involving single cast-iron check-valves, usually buried in the ground and commonly not even known to the water-works management, could not be permitted.

"A few of these manufacturers then proceeded to install special type double checks but most of them continued to 'stand pat,' or, while promising, to follow a procrastinating course. This they were able to do (1) because of the absence of any legislation and (2) because of the lack by this department of any adequate inspectional facilities.

"In 1919 a law was enacted in effect prohibiting the maintenance of a connection of this character, except such as might be approved by the state board of health. There was included a proviso that 'every valve, gate or other device for controlling or preventing the inflow of water of unapproved character into the public supply shall be of such construction as to permit of efficient inspection and testing, and an actual test thereof shall be made not less than twice annually by the individual, corporation or association furnishing water to the public.'

"A beginning was then made toward the eradication of the single iron checks and manufacturers, in response to their inquiries, were advised that the least that could be accepted was the device as now commonly in use, suitably installed in a test pit. At the present time 79 New Hampshire mills have these double check connections.

"Although recognizing that the ideal situation is one involving no connection whatsoever between a public water supply and a polluted industrial source, yet, with us it is a case of doing the best thing possible in view of existent facts. While admitting that no such device affords an infallible means of protection, yet it also cannot be denied that no form of protective action against a polluted water supply can be said to be infallible, these depending, as all of them largely must, upon the human factor.

"Accordingly, it is the present policy of the New Hampshire Board of Health to permit, for the purpose of fire protection only, of the use, in lieu of mechanical severance, of a suitable connecting device of the best approved type, providing also that such be installed in a proper test pit, and maintained under periodic inspection."

In December, 1926, the Rhode Island State Board of Health, while without authority to prevent the installation and use of cross-connections, adopted a resolution advising that all such be abolished.

In its bulletin of January 1927, the Connecticut State Department of Health published an article by the Director of its Bureau of Sanitary Engineering. In this article, the author cites the regulations of the department, namely, that after December 31, 1926, no cross-connections shall exist between potable and non-potable supplies, except that installations pro-

tected by double check-valves of approved type with adequate facilities for testing that were in existence on December 31, 1926, may be temporarily continued, with the approval of the State Department of Health. The latter provision was inserted because it was felt that double check-valves of the latest approved type should be given a fair trial. The length of extension of time granted will depend upon investigations that the department is now making as to the efficiency of the newest types of valves. No new installations of double check-valves are allowed.

In New York State the Public Health Council of the State Department of Health adopted on November 12, 1925, an amendment to its sanitary code which prohibited cross-connections between non-potable and potable water supplies after July 1, 1926. This regulation permitted the continuance of cross-connections where two gate-valves with indicator posts and two check-valves of the special design of the Factory Mutual Fire Insurance Companies or equal were installed, but such connections were to be discontinued after July 31, 1928. The regulation also permitted the use of dual water-supply systems where the auxiliary supply was delivered to an elevated tank, provided the connections were made through an open discharge pipe above the high-water line of such tank. Final decision on policy in New York State remains unsettled at this writing.

In New Jersey a new chapter to the sanitary code was submitted to the State Department of Health on April 21, 1927, by the Chief of the Bureau of Engineering. This chapter would prohibit any cross-connections, by-pass valve or auxiliary intake, or other similar device which may permit any flow of water into an approved public potable water supply from any other supply of water, . . . unapproved by the State Department of Health or not treated in accordance with these regulations. It permits physical connections with another approved public potable supply and with approved private potable supplies, "regularly examined as to purity by those in charge of the approved potable public water supply with which the connection is to be made and also regularly examined by the State Department of Health, provided there shall be no connection between the approved private potable water supply and water supplied from a source polluted or subject to pollution."

This recommendation was made on June 28, 1927, and was to become effective immediately, except that the time of discontinuance of connections could be extended to January 1, 1928, in cases where the connection between an approved public supply and any other water supply included double check-valves of the Factory Mutual type, installed as specified by the State Department of Health of New Jersey. This time has recently been extended.

The Manufacturers' Association of New Jersey has requested an amendment to the new chapter which would permit permanent cross-connections through double check-valves, provided that at least quarterly tests for tightness and annual internal examinations and cleaning be made jointly

by accredited representatives of the owner and of the municipality and that the results of these tests and inspections be reported to the State Department of Health. "The demand for this proviso," it is stated in the report, "demonstrates that such an installation is not absolute protection."

General Code of the State of Ohio, Section 1252-3.

"It shall be unlawful for any official, officer, or employee having in charge or being employed in the maintenance and operation of a public water supply and water-works system or for any other person, firm or corporation to establish or permit to be established any connection whereby a private, auxiliary or emergency water supply other than the regular public water supply may enter the supply or distributing system, unless such private, auxiliary or emergency water supply, and the method of connection and use of such supply shall have been approved by the State Department of Health."

Other states have made similar regulations but the above will suffice for illustration.

Action of the American Water Works Association. The fire-protection division of the American Water Works Association adopted the following resolutions at Louisville, Kentucky, May, 1925:

"WHEREAS cross-connections between potable public water supplies and supplies from other sources have been the cause of a large number of outbreaks of typhoid fever and other water-borne diseases, and

"WHEREAS, check-valves and other similar protective devices cannot always be depended upon, be it

"RESOLVED, that no physical connection should be permitted between a potable public water supply and any other supply except as follows:

1. With another potable public supply.
2. With a potable supply which is regularly examined as to its quality by those in charge of the potable public supply to which the connection is made.

"This prohibition to apply to all piping systems either inside or outside of any building or buildings, and

"BE IT FURTHER RESOLVED, that definite programs should be inaugurated in each municipality to permanently eliminate all other connections.

Action of the Conference of the State Sanitary Engineers. The following resolutions were adopted in 1926 by the Conference of State Sanitary Engineers:

"WHEREAS, cross-connections, auxiliary intakes and by-passes between potable public water supplies and supplies from other sources have been the cause of a large number of outbreaks of typhoid fever or other water-borne disease, and

"WHEREAS, check-valves and other protective devices, or notifying the public in the case of using water from a polluted source through an auxiliary intake or by diverting the flow around an integral part of a purification plant through a by-pass, cannot be depended upon to adequately protect the public from disease,

"BE IT RESOLVED, that no physical connections should be permitted

between any potable public water supplies either through cross-connections, auxiliary intakes or by-passes and other supplies except as follows:

1. With another potable public water supply.
2. With a potable supply which is regularly examined as to its quality by those in charge of the potable public supply to which the connection is made.

"This prohibition to apply to all piping systems, either inside or outside of any building or buildings, and be it,

"FURTHER RESOLVED, that definite programs should be inaugurated in each state and each municipality thereof to permanently eliminate all other connections, and be it,

"FURTHER RESOLVED, that the Executive Committee of this conference transmit copies of this resolution to the Fire Underwriters Association and related organizations, also the American Water Works Association, New England Water Works Association and other analogous organizations with the request that they coöperate in securing the carrying out of the provisions of this resolution."

The full report of a special committee of the Conference is appended as Appendix C.

In its report which recommended this resolution for adoption by the Conference, the committee defined cross-connections, auxiliary intakes and by-passes; presented a tabulation of outbreaks of typhoid fever and in some instances of enteric diseases traceable to cross-connections, auxiliary intakes and by-passes. This tabulation includes a total of 8 028 cases of typhoid fever with 226 deaths and also more than 11 000 cases of enteric disturbances.

Appended to the report are the results of the questionnaire summarizing the procedure for elimination of cross-connections, etc. As an example of what may be done, the experience at Chicago may be cited. A survey disclosed 428 cross-connections of which 179 were direct and 249 indirect. By the end of 1925, 85.3 per cent. of these connections had been removed.

Legal Liability. The legal cases cited in the report of the state sanitary engineers support the position that municipalities that through their officers permit cross-connections with polluted supplies become legally responsible for any epidemics resulting therefrom. In the opinion of the committee they become legally liable if the epidemics result from any negligence in the design, installation, operation or inspection of said connections. It is also true that equal, if not greater, responsibility rests upon state authorities regarding cross-connections even though it be moral rather than legal.

Relative Hazards. In the 296 cases of interruption or failure of water supplies, recorded by the Associated Factory Mutual Fire Insurance Companies, there were 12 cases where fires occurred simultaneously.

In the 8 028 cases of typhoid and over 11 000 cases of enteric disturbance, resulting in 226 deaths, the losses by death and disability reached millions of dollars. Most of the deaths followed pollution passing through single valves or checks.

Apparently any single valve is too hazardous a connection between a

potable and a polluted water supply, and even the best installation of double check-valves may fail for lack of inspection.

Importance of Inspection. Where double check-valves are inspected frequently and where they are thoroughly overhauled annually, the danger due to cross-connections is greatly reduced. The permissibility of the best installation, other things being equal, therefore, hinges upon the frequency and kind of inspection.

Results of inspection of 1 032 sets of double check-valves by the Associated Factory Mutual Fire Insurance Companies showed only four cases where both valves were leaky, and in these four leakage was slight and due to lack of care. An instance has been cited*, however, where both clappers of a double check-valve installation were held partly open by a pair of overalls, thus again emphasizing the necessity for frequent inspection. (Appendix E.)

Data regarding cross-connections in New Bedford are of interest. Here the check-valves are inspected at least twice a year, and the results show both valves leaking in two out of 2 152 tests or less than one case in 1 000 inspections. Many of the installations were not of the latest type. A table summarizing the essential data relative to the tests is appended. (Appendix D.)

The results of the first year of periodical testing of double check-valves by the State Department of Health of Connecticut show that out of 624 tests on iron-body check-valves, there were 24 cases where one leaky valve was found and one case where both valves were found to be leaking because of unevenness in the flat, rubber seat-facings. Of 273 tests of the all-bronze valves, leaky valves (outside only) were found in 3 cases and in no case were both valves leaking. (A summary of the results of these tests is given in Appendix F.)

In view of the large number of cases of sickness and death, the neglect of even the best device is dangerous. No pains should be spared to make inspections thorough. The Committee realizes the difficulty in establishing a procedure that will prove effective for all conditions, all types of installation and all places. To indicate broad general principles rather than routine procedure seems to be the work of this committee. Nevertheless, it is believed that good results may be obtained by quarterly inspections. Furthermore, the Committee believes that, where possible, inspections should be made through the coöperative efforts of both state and municipal authorities on the one hand and the mill owners and insurance companies on the other. Installations in each municipality should be examined by a state official at least once a year.

The attention of water departments is called to the frequency of unknown and unprotected connections, not only as regards their existence but also as regards their type and condition. This relates particularly to old installations. All connections should be sought out and, when found, should be abolished or protected.

*Jour. N. E. W. W. A., Vol. xxxvi, p. 406.

The Committee appreciates the coöperation of the insurance companies as exemplified by the action of the Associated Factory Mutual Fire Insurance Companies who are chiefly interested in the protection of factories and mills as contrasted with general fire protection. These companies at their executive meeting on December 12, 1927, adopted the following procedure:

"a. See that every set of double check-valves, both old and new, receives the necessary supervision. Experience has shown that many risks do not appreciate the importance of keeping the double check-valves clean and tight by means of an annual overhauling. Our work would be in the line of education and assistance."

"b. Pending the decision in each case as to the final outcome, see at once that every single check-valve between potable and non-potable supplies is made accessible and kept tight as is being done in the State of Massachusetts."

"c. Make a study of fire-service connections at our plants both insured or prospective, and determine where it would be wiser to eliminate cross-connections and where best to provide other supplies. Then for those risks where cross-connections should be retained, have all-bronze double check-valves put in and provide for periodic and effective supervision of them as outlined in paragraph 'a' above."

As representing the attitude of other insurance companies the following may be quoted from a letter of Mr. George W. Booth, Chief Engineer, National Board of Fire Underwriters, published in the June 3, 1920, issue of the *Engineering News-Record:*

"The fire-protection engineer is not the responsible party in making the connection originally or in its continuance. Insurance standards require, for complete reliability, two independent sources of supply, and the plant management or the municipal authorities may, and often do, use one source which is unsafe or questionable from a sanitary standpoint, for the reason that it is a cheaper or easier one.

"The engineers of the National Board of Fire Underwriters do not, and we believe other engineers should not, favor such connections, but there are cases where they have already been made, and it is not possible, without the charge of discrimination, to refuse credit for them as emergency sources. It is, however, standard practice with many of the insurance bureaus to recommend secondary sources of supply which will be safe, as for instance, a storage reservoir.

"The double check-valve, designed some years ago for use on connections to sources of doubtful quality, has been permitted by some health authorities and has a satisfactory record. It should be installed most carefully and be maintained under a thorough inspection system."

Conclusions. The Committee recognizes that the only absolute safeguard for the purity of water supplies is complete separation of potable and non-potable supplies. Many cases exist in industrial as well as fire lines where cross-connections can be entirely eliminated without extensive changes or undue hazard to life and property. Such connections should be immediately abolished. In other instances the abolition of such cross-

connections presents a very serious problem from the standpoint of possible loss of life and property by fire. Each case should be carefully studied on its own merits to determine the best procedure, all interests being considered. So far as possible steps should be taken in each community to provide public water supplies of sufficient adequacy and reliability, even to providing a secondary potable supply if necessary, so as to eliminate the necessity for cross-connections of any kind.

The Committee feels that pending the establishment of adequate and reliable supplies for protection of life and property from fire, experience to date indicates that double check-valves of the latest improved type, properly installed and adequately supervised, furnish the best protection of any device now known. It is essential, however, that such installations be regularly and frequently inspected and tested. Installations of this type are relatively recent and whether or not such installations, properly supervised, give sufficient protection, is a question that is still open for decision on the basis of further experience.

Your Committee does not advise the use of double check-valves as protection against supplies that are subject to gross pollution by sewage or industrial wastes nor against supplies that are subject to more or less frequent direct pollution by human wastes from nearby sources. Theoretically, the best double check-valves may fail, and although present experience indicates that the danger of such failure is relatively small, this danger to health must be carefully balanced against the fire hazard to life and property.

The elimination of cross-connections is bound up with the approval of the quality of auxiliary supplies and with local influences which may introduce complications, so that it seems to your Committee that regulations relative to cross-connections should be adopted by properly authorized state bodies. This does not mean, however, that a large degree of responsibility should not rest upon the management of a water supply maintaining cross-connections.

While this report is largely concerned with cross-connections for fire service, there are many other cross-connections like those with sewers, around water-purification plants and through auxiliary intakes. None of these should be permitted.

Your Committee recommends that the following resolution be adopted by the Association:

"WHEREAS, evidence shows that the existence of certain cross-connections between potable and non-potable water supplies has resulted in many outbreaks of disease and many deaths, and

"WHEREAS, such cross-connections are admittedly a hazardous part of any water-supply system

"WHEREAS, it is necessary not only to protect water supplies from pollution but also, to safeguard property and life against fire,

"THEREFORE, be it resolved that the New England Water Works Association places itself on record as follows:

"1. The Association urges the development of all public potable water supplies to a state of sufficient adequacy and reliability, even to providing a secondary potable supply if necessary, so as to eliminate all such cross-connections.

"2. The Association recommends that all such cross-connections, including emergency intakes and by-passes, which can be abolished without undue fire hazard to life and property be immediately eliminated.

"3. Pending such elimination double check-valves of the latest improved type, properly installed and adequately supervised are considered to be the best safeguard, now known, for minimizing the hazard of pollution through cross-connections where local conditions indicate the need for such connections.

"4. Even with the best double check-valve installations, some possibility of pollution remains and for this reason no cross-connections whatever should be allowed where secondary supplies are of a raw-water quality which would be bacteriologically unsafe even with purification or where proper installation and supervision are not maintained.

"5. The Association strongly urges that states adopt suitable laws and regulations covering the control of cross-connections and that in each community an investigation of the existing cross-connections be made immediately and a program for the control thereof be inaugurated by the local authorities.

6. The Association recommends that where possible the inspections be made through the coöperative efforts of state and municipal authorities on the one hand and owners and insurance companies on the other. Inspections should be made at least quarterly by an official responsible for the quality of the public water supply; devices should be overhauled yearly."

Respectfully submitted,

ROBERT SPURR WESTON, *Chairman*,
JOHN S. CALDWELL,
E. SHERMAN CHASE, *Secretary*,
STEPHEN DeM. GAGE,
CHAS. D. HOWARD,
ARTHUR C. KING,
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WARREN J. SCOTT,
STEPHEN H. TAYLOR,
ARTHUR D. WESTON.

March 14, 1928.

APPENDIX A.

EXAMPLES OF COMMON CROSS-CONNECTIONS TO POTABLE WATER SUPPLIES.

A. Cross-Connections Where Secondary Supply is Available and Connected:

I. *Fire Service:*

Pipes for:

(1) Sprinklers and hydrants.
(2) Pump priming.
(3) Drinking water taken off sprinkler system or yard mains.

II. *Industrial Use:*

Pipes for:

(1) Boiler feed.
(2) Washing. Examples: paper-making processes; textile industry; tanning industry; dairying processes, etc.
(3) Cooling. Examples: condensers; mills — rubber industry; mills — pyroxylin plastic; bearings; dairying processes, etc.
(4) Quenching. Examples: coal and tar products; wire works, foundries, etc.; metal-finishing plants.
(5) Process work. Examples: dye kettles — textile and leather industries; paper manufacturing; gas manufacture, etc.

III. *Mill-Use and Supply of Hotels and Office Buildings:*

Pipes for:

(1) Drinking supply — secondary supply of questionable character.
(2) Toilet supply (especially in case of direct-pressure flushing hoppers).
(3) Washing in sinks.
(4) Bathing (including swimming pools).
(5) Hydraulic elevators, lifts, presses, etc.
(6) Pressure regulation.
(7) Injectors.

IV. *Sewers (either direct) or (indirect through tanks).*

B. Connections to tanks, barrels, cisterns and reservoirs that are filled with chemicals or in which the water is purposely made non-potable preparatory for use in:

Paper industry.
Textile industry.
Boiler feed.
Farming or hot-houses, etc.

In these cases no secondary supply is used and no pressure exists other than a head due to height of water in receptacle. In the event of negative pressure in supply piping, the water may siphon into drinking-supply mains.

Types of Cross-Connections:

(1) *Physical cross-connections* where dual supplies under pressure are permanently connected — protected usually by gate-, globe- and check-valves with various combinations.
(2) *Temporary connections* — swing joint provided where dual supplies are made available at the point of use but where little possibility exists of polluting potable supply.

(3) *Filler piece* — usually flanged — which, when removed from line, breaks cross-connection but when actually in place is same as physical cross-connection.

(4) *Open connections* — tanks that are open to atmospheric pressure may be filled from dual supplies:

(a) Where both feed pipes enter bottom and supply pipe taken from bottom — pressure on potable supply due to head of water in tank.

(b) Where polluted feed line enters the bottom — potable feed located above ordinary water level in tank.

(c) Where polluted feed line is located above ordinary water level — potable feed line enters bottom of tank — same as (a).

APPENDIX B.

PARTIAL LIST OF EPIDEMICS CAUSED BY POLLUTED WATER ENTERING DRINKING-WATER SYSTEMS THROUGH CROSS-CONNECTIONS.

The following constitutes a brief abstract of 25 instances of record in which drinking-water supplies have been polluted by entrance through cross-connections of unsafe water used for industrial purposes or for fire protection.

In 19 of these instances the cross-connection contained a single gate- or check-valve, in 3 instances protection against back-flow was afforded by two gate-valves or by a check-valve and a gate, and in one instance there were two gate-valves and a check-valve in series on the cross-connection. In one instance it might be assumed from the wording of the published record that protection against pollution was afforded by two gate-valves and a double check-valve arranged in series, although this was not definitely stated. In another case, however, such an arrangement was so stated.

These various instances may be classified as follows:

I. Protection by Single Gate- or Check-Valve.

A. Valve Leaked.

Albany, N. Y. Health News, New York State Dept. Health. November 21, 1927.

Epidemic of diarrhea followed by 30 cases of typhoid caused by polluted water from industrial supply leaking into city mains. There were three cross-connections, each of which was guarded by one or two gate-valves. Industrial supply pressure in excess of city pressure.

Bloomington, Ill., Jan. 1920. *Eng. News-Record*, Vol. 84, 939.

Industrial supply of Chicago and Alton Shops cross-connected with city supply. The creek from which the industrial supply was obtained went dry and a 33-inch sewer main was tapped. A leaky valve permitted this sewage to enter the municipal supply. There were 300 to 400 cases and 15 deaths from typhoid.

Philadelphia, Pa., 1920. *Eng. News-Record*, Vol. 84, p. 1 187.

Tastes and odors in the drinking water led to an investigation of the piping system at the Philadelphia Navy Yard in 1920. Several leaking single check-valves in cross-connections that were shown on piping plans of the Navy Yard were eliminated but the situation was not remedied. An unknown leaky check-valve, later found in an inaccessible place through which polluted river water, used for boiler purposes, leaked into the city system. Many cases of dysentery resulted.

Tiverton, R. I., 1926. *Bulletin*, R. I., State Board of Health, December, 1926.

Cross-connection with leaky gate between drinking-water tank and tank on fire supply in industrial plant. Fourteen cases and one death from typhoid.

Wausau, Wis. Eng. News-Record, Vol. 92, p. 348.

A factory epidemic in Wausau, Wisconsin, traced to a faulty valve in a cross-connection. Other details not given.

Winnipeg, Manitoba. *Eng. News-Record*, 1910, p. 677.

Polluted Red River water was used for secondary fire supply and boiler feed. A leaking valve allowed domestic service to be polluted. Twenty-five cases of typhoid.

Winona Lake, Ind., June 1925. *Pub. Health Reports*, Aug. 21, 1925.

Leaking valve on cross-connection between public supply and a polluted industrial supply caused many cases of typhoid among convention visitors. This cross-connection installed contrary to an order of Board of Health.

Elgin, Ill., 1916. *Jour. A.W.W.A.*, Vol. 15, No. 5, p. 477.

Leaking valve on cross-connection with a factory supply resulted in 18 deaths. Type of valve not stated.

Lawrence, Mass., 1903. JOUR. N.E.W.W.A., 1922, p. 406.

Leaking check-valve on cross-connection with mill supply caused 43 cases of typhoid.

Springfield, Ohio. 1911 Report, Ohio State Bd. of Health, p. 469.

Leaky check-valve caused 12 cases of typhoid.

Philadelphia, Pa. *Jour. A.W.W.A.*, Vol. 6, p. 750; Annual Report Bureau of Health, Philadelphia, 1913, pp. 116 and 308.

More than 300 cases of typhoid and many deaths were traced to cross-connections. An investigation showed many check-valves leaking.

Minneapolis, Minn., 1918. *Jour. A.W.W.A.*, Vol. 6, p. 773.

Leaking check-valves in cross-connections caused 18 cases and 6 deaths from typhoid.

Greystone, R. I., 1917. *Bull.* R. I. State Bd. of Health, Oct. 1917.

Forty cases of typhoid and 4 deaths probably caused by neglect to properly close gate-valves on a cross-connection between polluted industrial supply and drinking-water supply.

Milwaukee, Wis., 1912. *Jour. A.W.W.A.*, Vol. 6, p. 749.

Public supply polluted by leaking check-valves in cross-connections.

Moline, Ill. *Jour. A.W.W.A.*, Vol. 6, p. 230, 1927.

Factory supply from Mississippi River cross-connected with city supply at approximately 20 points. Investigation showed leaking check-valves probably responsible for typhoid outbreak.

B. Single Valve or Gate "Not Closed."

Rockaway, N. J., 1923. *Eng. News-Record*, Vol. 91, p. 267.

The single check-valve on a cross-connection between a fire supply and the municipal supply was "stuck open and so encrusted with dirt and rust that the flap could only be moved by the use of a bar." The fire supply was polluted by the effluent from a septic tank receiving excretions of a typhoid carrier. Temporary reduction in pressure caused fire supply to flow into town mains. Forty-one cases and 4 deaths from typhoid resulted.

Van Wert, Ohio, 1913. *Jour. A.W.W.A.*, Vol. 15, p. 477.

Sudden drop in pressure on city supply caused in flow of polluted water from polluted private supply of C. & N. R. R. Shops. Six hundred cases of sickness; 25 cases and 2 deaths from typhoid.

Everett, Wash., 1923. *Jour. A.W.W.A.*, Vol. 15, No. 5, p. 477.

Polluted industrial supply entered through open 6-in. gate. Drop in city pressure caused introduction of polluted water through open 6-in. cross-connection with an industrial supply. Two thousand cases of diarrhea; 77 cases and 11 deaths from typhoid.

Lowell, Mass., 1903. *Jour. A.W.W.A.*, Vol. 15, No. 5.

Check-valve on cross-connection between municipal and fire supply failed to close after a fire, permitting polluted water to enter city mains. Epidemic of dysentery, followed by 196 cases and 16 deaths from typhoid.

II. Protection by Two Gates or Checks in Series.

Franklin Furnace, N. J. *Eng. News-Record*, Vol. 89, pp. 959 and 1 045, Vol. 91, p. 429.

An open gate-valve and a check-valve on cross-connection between municipal and industrial supplies at N. J. Zinc Co. allowed polluted water to enter town supply, causing one hundred fourteen cases and 18 deaths from typhoid.

Sterling and Rock Falls, Ill., 1924–25. *Eng. News-Record*, Vol. 94, p. 526.

Polluted river water leaked by a globe-valve and a single check on cross-connection in a factory. Twelve cases and 2 deaths from typhoid.

Cohoes, N. Y. *Health News*, New York State Dept. Health, November 21, 1927.

Forty-seven cases of typhoid caused by pollution of city supply by Mohawk River water entering through cross-connection with industrial supply. Two gate-valves in series on connection operated once, and city pressure low five times just prior to outbreak.

III. Protection by Three or More Gates or Checks in Series.

Fort Wayne, Ind., 1923. *Engineering News-Record*, Vol. 92, p. 348.

Leakage by two gate-valves and a check-valve in series on a cross-connection at Penn. R.R. plant caused pollution of city supply. One hundred fifty cases and 22 deaths from typhoid.

Oswego, N. Y. *Health News*, New York State Dept. Health, November 21, 1927.

Many cases of diarrhea and 9 cases of typhoid in a factory traced to pollution of drinking water through cross-connection with industrial supply. Cross-connection protected by two globe-valves and two check-valves in series.

IV. Unclassified.

Circleville, Ohio, 1914. *Jour. A.W.W.A.*, Vol. 5, p. 447.

Polluted water from private supply leaked through two gates and two checks into city mains. Forty-three cases and 2 deaths from typhoid.

In addition to the recorded instances of troubles due to pollution entering drinking-water systems through cross-connections, carrying non-potable water for industrial or fire-fighting purposes as listed above, the Committee of the Conference of State Sanitary Engineers and other authors have listed a considerable number of instances where trouble was occasioned by the introduction of polluted water through leaks in emergency intakes or from similar causes. There is no question that the elimination or adequate protection against such chances of dangerous pollution is important and necessary. As the function of this Committee appears to be definitely limited to a consideration of direct cross-connections, references to those other sources of danger have been omitted from the tabulation.

See also Appendix C.

APPENDIX C.

REPORT OF COMMITTEE ON CROSS-CONNECTIONS CONFERENCE OF STATE SANITARY ENGINEERS.

Buffalo, June 5–7, 1926.

Resolution Recommended.

The Fire Protection Division of the American Water Works Association adopted the following resolutions at its convention at Louisville, Ky., in May, 1925:

"*Whereas*, cross-connections between potable public water supplies and supplies from other sources have been the cause of a large number of outbreaks of typhoid fever and other water-borne diseases, and

"*Whereas*, check-valves and other similar protective devices cannot always be depended upon, be it

"*Resolved*, that no physical connection should be permitted between a potable public water supply and any other supply except as follows:

1. With another potable public supply.
2. With a potable supply which is regularly examined as to its quality by those in charge of the potable public supply to which the connection is made.

"This prohibition to apply to all piping systems either inside or outside of any building or buildings, and

"*Be it further Resolved*, that definite programs should be inaugurated in each municipality to permanently eliminate all other connections."

Your Committee believes that a similar resolution should be adopted by this Conference changing the words, however, to also include auxiliary intakes and by-passes. The following resolution is recommended for adoption:

"*Whereas*, cross-connections, auxiliary intakes and by-passes between potable public water supplies and supplies from other sources have been the cause of a large number of outbreaks of typhoid fever or other water-borne diseases, and

"*Whereas*, check-valves and other protective devices, or notifying the public in the case of using water from a polluted source through an auxiliary intake or by diverting the flow around an integral part of a purification plant through a by-pass, cannot be depended upon to adequately protect the public from disease,

"*Be it Resolved*, that no physical connections should be permitted between any potable public water supplies either through cross-connections, auxiliary intakes or by-passes and other supplies except as follows:

1. With another potable public water supply.
2. With a potable supply which is regularly examined as to its quality by those in charge of the potable public supply to which the connection is made.

"This prohibition to apply to all piping systems, either inside or outside of any building or buildings, and be it,

"*Further Resolved*, that definite programs should be inaugurated in each state and each municipality thereof to permanently eliminate all other connections, and be it

"*Further Resolved*, that the Executive Committee of this conference transmit copies

of this resolution to the Fire Underwriters Association and related organizations, also the American Water Works Association, NEW ENGLAND WATER WORKS ASSOCIATION and other analogous organizations with the request that they coöperate in securing the carrying out of the provisions of this resolution."

A report upon cross-connections by a similar committee at the meeting of the Conference in June, 1921, recommending elimination of such connections was formally adopted. In view of this report and the abundance of other data relating to the subject, your present Committee believes that only a brief, concise, final report is desirable at this time. This report, however, covers briefly the following subjects:

(1) Resolution recommended for adoption by the Conference.
(2) Definitions — cross-connections, auxiliary intakes, by-passes.
(3) Outbreaks of disease traceable to such connections.
(4) Liability of owners where disease is caused by use of polluted water.
(5) Program for elimination of cross-connections, auxiliary intakes and by-passes.

Definitions.

Cross-Connections. A cross-connection is a connection whereby a potable water-supply system is connected with another water-supply system, whether public or private, in such a manner that a flow of water into the potable supply is possible therefrom, either directly through the manipulation of gate-valves or because of ineffective check- or back-pressure valves.

Examples of cross-connections include connection between the piping systems of two supplies containing either check-valves or gate-valves, or both, such as are frequently used in industries to provide auxiliary supplies for fire protection or industrial purposes. It is not intended that a cross-connection will include those permitting water from a public supply to discharge into an elevated tank, cistern or suction well, at an elevation above its high-water line or with a tank wholly supplied from the public supply and properly protected against contamination.

Auxiliary Intake. An auxiliary intake is any piping, connection or device whereby water may be secured from a source other than that normally used.

Such connections include an auxiliary intake into a river or lake where water for domestic purposes is normally secured from another source; also conditions wherein water may be pumped from another source either by the owner of the supply or other agencies into the regular distribution system.

By-Passes. A by-pass is any system of piping or arrangement whereby the water may be diverted around any part or portion of a water-purification plant.

Such connections include arrangements whereby the coagulating basin, filters or sterilization equipment of a water-purification plant may be by-passed.

Outbreak of Disease.

Appended is a tabulation of recorded outbreaks of typhoid fever and in some instances of a dysentery that have been caused by cross-connections, auxiliary intakes and by-passes. This tabulation includes a total of 8 028 cases of typhoid fever with 226 deaths; also more than 11 000 cases of dysentery. Other outbreaks have, undoubtedly, occurred that have not been definitely recorded or that have not been found in the search of references by your Committee. In any event the sickness and deaths are somewhat appalling and sufficient to cause any group of officials to give careful consideration to necessary steps to eliminate such dangers. The tabulation and data are presented primarily as reference for members of the Conference in presenting this question to secure the elimination of these dangerous devices.

Liability.

Courts have held on numerous occasions that the owner of a water supply, whether a municipal or a private concern, is liable for damages caused by sickness resulting from the use of a polluted water furnished by him. Below is recorded a synopsis of some such decisions:

Green v. *Ashland Water Co.* (1898) 101 Wis. 258: "If defendant knew, or from the situation ought to have known, the water it is distributing was dangerous for domestic use, from some cause not discoverable ordinarily by the exercise of reasonable care, it owed the duty to its customers of disclosing that danger, and a failure so to do, knowing that such customers were liable to use the water through ignorance of its character, was a fraud in law, rendering the defendant liable to legal damages to any person injured by such fraud without fault on his part, and it was also a failure of duty amounting to actionable negligence as well, to which the same liability is incident." Five thousand dollars verdict involved.

Lockwood v. *Dover* (1905) 73 N. H. 209: Negligence was alleged in that defendant municipal corporation failed to clean out its water pipes or to provide means whereby they could be cleaned out, and that in consequence thereof foreign and decayed matter became lodged in the city's pipes, entered the pipes leading to the plaintiff's dwelling and was there drunk by the plaintiff's intestate, causing him to sicken and die. It was held that the defendant was liable.

East Grand Forks v. *Luck* (1906) 97 Minn. 373: Based upon a study of the following cases: *Reed* v. *City of Anoka*, 85 Minn. 294, 88 N. W. 981; *Walla Walla City* v. *Walla Walla Water Co.*, 172 U. S. 1, 19 Sup. Ct. 77, 43 L. Ed. 341; *Illinois Trust & Savings Bank Co.* v. *Arkansas*, 76 Fed. 271, 22 C. C. A. 171, 34 L. R. A. 518, Judge Elliott said: "When the municipality enters the field of ordinary private business, it does not exercise governmental powers. Its purpose is not to govern the inhabitants, but to make for them and itself private benefit. As far as the nature of the powers exercised is concerned, it is immaterial whether the city owns the plant and sells the water, or contracts with a private corporation to supply the water. It is not in either case, exercising a municipal function . . . . When a municipality engages in a private enterprise for profit, it should have the same rights and be subject to the same liabilities as private corporations or individuals.

Keever v. *Mankato* (1910) 113 Minn. 55: "When a municipality voluntarily engages in selling and distributing water to customers for its local advantage or profit, it enters the field of ordinary private business, and has the same rights and is subject to the same liabilities as private corporations or individuals with respect to damages from impurity

of the water. . . . It is obvious that a sound public policy holds a city to a high degree of faithfulness in providing an adequate supply of pure water. Nor does it appear why the citizens should be deprived of the stimulating effects of the fear of liability on the energy and care of its officials; nor why a city should be exempt from liability while a private corporation under the same circumstances should be held responsible for its conduct and made to contribute to the innocent persons it may have damaged. Five thousand dollars awarded.

Jones v. *Mount Holly Water Co.* (1915) 87 N. J. L. 106: "Water is a necessity of life, and one who undertakes to trade in it and supply customers . . . is bound to use reasonable care to see that whatever is supplied for drink . . . shall be reasonably pure and wholesome, and that negligently furnishing water which is deleterious to that human body or health will furnish a valid cause of action to a customer injured by the use of the water." "Actual notice or knowledge of the unwholesomeness of the water of the defendant company was not an essential element to be proven in order to establish the defendant's liability; it was sufficient if there was testimony tending to show that the defendant, in the exercise of reasonable care, might have discovered the unwholesomeness and dangerous condition of the water." Seven hundred fifty dollars awarded.

Vennen v. *New Dells Lumber Co.* 154 N. W. 640: The facts in the case were briefly these; The employing company had a dual water supply in its factory; one source obtained from the city mains, the other from a nearby stream which was badly polluted. The two water distribution systems were connected by a pipe in the boiler room protected by a Globe valve reinforced by a check valve set against the polluted supply. A number of employees were in the habit of obtaining drinking water from a faucet in the boiler room which was located so that the polluted river water could reach it. Subsequent to the epidemic of 13 cases of typhoid fever and two deaths, the valves were examined and found leaky. The court held on the demurrer of the defendant that typhoid fever was a compensable accidental injury. Sued for $20,000.

It is significant that in another case — *Alex Vander Leest* v. *John Hobert Company*, Industrial Commission of Wisconsin Workmen's Compensation 10th Annual Report, July 1, 1921 to June 30, 1922, page 59, it was held by the Industrial Commission that compensation was due nineteen employees of the company who had contracted typhoid fever by use of water from a polluted well of the company. This case, however, was not carried into the courts. Compensation awarded $2,233.61, medical aid $1,742.94. Total $3,976.55.

Stubbs v. *City of Rochester* (1919) 226 N. Y. 516: One seeking to hold a city liable for injury by typhoid fever, alleged to have been contracted from defendant's polluted water system, is not bound to eliminate all other possible causes of the disease to establish defendant's liability. That a city's contaminated water supply was the source of typhoid fever in a citizen may be found from the fact that he drank water near the point of contamination, that some sixty (60) other cases developed in that vicinity, that his habits were such as to tend to exclude another probable source, while his physician testified that such contamination was the source of his illness.

Canavan v. *City of Mechanicsville*, 128 N. E. 882: A private water company or a municipality is not an insurer, nor liable as a guarantor, of the quality of the water it furnishes to its customers by the customary means of pipes and faucets, and cannot be held liable for injuries caused by impure water furnished by it, unless it knew or ought to have known of the impurity. Its duty is that of exercising reasonable and commensurate care and diligence in providing an adequate supply of wholesome water at all times.

In the case above cited the court decided that the complaint stated a valid cause of action against the defendant city on account of typhoid fever contracted by plaintiff and his children from drinking impure water.

Roscoe v. *City of Everett*, 239 Pacific 831: In discussing the case the court said: "It is sufficient to say that the evidence discloses that on April 11, 1923, a six-inch main was

laid to connect two laterals, and that when the connection was so made it permitted free circulation of water to the city users in the district served, and also better service to the Eclipse Mill Company. At the time this connection was made, there was a by-pass which had existed for a great many years. With the making of the connection there was no longer any need for the by-pass. This by-pass had in it what is known as a gate valve A — a valve worked by hand, and which when closed, effectually prevented water from passing through the pipe." . . . "There was evidence that the city never inspected the valve in the by-pass from the date of its installation." . . . "The ease with which the valve could be sealed or by-pass removed and the eminent danger to be apprehended by failure so to do are strong factors in the question of the city's negligence." Award $60,000.

Procedure for Elimination of Cross-Connections, etc.

To secure data in regard to policies being following by different State Boards of Health, questionnaires were sent out, thirty-one (31) replies being received. The questionnaire with a summarization of the answers is recorded below:

(1) Are cross-connections permitted between public water supplies and polluted factory supplies in your State? If so, under what conditions?

(a) All cross-connections prohibited	10
(b) New cross-connections prohibited	6
(c) No definite control	7
(d) Permitted with double check-valves as protection	8
	31

(2) Are auxiliary intakes whereby a polluted supply may be utilized instead of the regular public supply in case of emergency, permitted? If so, under what conditions?

(a) Auxiliary intakes prohibited	12
(b) Permitted when protected as by removing a section of the pipe	12
(c) Permitted on condition State Board of Health notified when used	5
(d) Unanswered	2
	31

(3) Are by-passes whereby any important part of a water-purification plant may be by-passed thus discharging polluted water into a public water supply, permitted? If so, under what conditions?

(a) By-passes prohibited	17
(b) Permitted with protection as by removing a section of the pipe	10
(c) No definite control	2
(d) Unanswered	2
	31

(4) What are your rules and regulations or manner of enforcement in each of the above?

(a) Definite regulations regarding cross-connections, auxiliary intakes and by-passes	6
(b) Definite regulations regarding cross-connections only	3
(c) General control as matter of policy without specific regulations	5
(d) Regulations for by-passes only	1
(e) Have power to make, but have not enacted regulations	7
(f) No regulations	9
	31

(5) What trouble have you experienced in the elimination of cross-connections, auxiliary intakes and by-passes in connection with the Underwriters Standards?

(a) No trouble	17
(b) Underwriters have objected to changes	4
(c) No definite information	10
	31

From questionnaires to states by Committees of the Conference, it is noted that in 1921 three states had regulations prohibiting all cross-connections with a public water supply and in 1926 eight states had such regulations.

There is evidently a general movement by most states toward the elimination of cross-connections. In some instances all cross-connections are prohibited, in others new cross-connections are prohibited but those existing are permitted to remain providing they are protected with double check-valves and in some states double check-valves are permitted also on new installations. One state, New York, prohibits new cross-connections and has set a definite time for the complete elimination of all cross-connections.

Your Committee believes that it is an accepted opinion that all cross-connections, auxiliary intakes and by-passes should ultimately be eliminated. The policy to be followed in bringing this about, however, depends largely upon local conditions and the procedure must be determined by the individual states. This report, therefore, does not attempt to set up a definite policy in securing the elimination of these connections but suggests the following as a possible procedure:

1. Adoption, publication and distribution of regulations by the State Department of Health —

(*a*) Prohibiting new cross-connections,

(*b*) Requiring the elimination of all existing cross-connections as soon as possible.

2. A survey of all cross-connections with public water supplies directly by the State Department of Health if possible or otherwise a survey by each municipality with definite reports back to the Department.

3. A definite follow-up program by correspondence and inspections to see that the regulations of the Department are carried out.

Typhoid Epidemics Caused by Cross-Connections, Auxiliary Intakes and By-Passes.

A. Cross-Connections.

Place.	Year.	Typhoid.		Intestinal Disturbances.	References and Remarks.
		Cases.	D'ths.		
Amsterdam, N. Y.	1920	22	1	....	Reports on File.
Auburn, N. Y.	1908	58	..	....	J. N. E. W. W. A. Vol. 24, p. 407.
Binghamton, N. Y.	1923	13	..	....	Report on File.
Bloomington, Ill.	1920	130	15	400	J. A. W. W. A. Vol. 7, p. 560.
Bluff Point, N. Y.	1916	15	?	....	Health News, N. Y. St. Dept. Health, Oct. 1920.
Circleville, Ohio	1914	43	3	?	Ohio St. Bd. Health Rpt. 1914, pp. 724–730.
Eau Claire, Wis.	....	13	2	....	154 N. W. 640.
Elgin, Ill.	1916	Many	18	?	J. A. M. A. 1917, Vol. 68, p. 465.
Everett, Wash.	1923	77	?	2 000	U. S. P. H. S. Rpts. 1924, Vol. 39, No. 13, pp. 605–611.
Fort Wayne, Ind.	1923	150	22	?	E. N.-R. Vol. 92, p. 348, 1924.
Franklin, N. J.	1922	114	18	?	E. N.-R. Vol. 89, pp. 959–1 045, 1922; Vol. 91, pp. 429–1923.
Hartford, Conn.	1918	?	?	?	E. N.-R. Vol. 87, No. 10, 1921, pp. 409–11.
Hyde Park, Mass.	1907	Several	?	?	J. N. E. W. W. A. 1922, p. 406.
Lawrence, Mass.	1903	43	?	?	J. N. E. W. W. A. Vol. 22, p. 235.
Lowell, Mass.	1903	172	9	Thousands	J. A. M. A., 41; 151–5, 1903; Proc. A. M. W. A. 1913, p. 153; E. N.-R. 51:125.
Mannington, W. Va.	1916	Several	?	?	J. A. W. W. A. Vol. 6, p. 752.
Maywood, Ill.	1920	0	0	75	Bull. Ill. Dept. Health, Cir. No. 7; Nation's Health, June, 1926; E. N.-R. 86: 310, 1921.
Mechanicsville, N. Y.	1920	15	?	?	Report on File.
Massachusetts	Three	instances			J. A. W. W. A. Vol. 6, p. 753.
Milwaukee, Wis.	1912	?	?	?	J. A. W. W. A. Vol. 6, p. 749; Kee W. W. An. Rpt. 1912, p. 21.
Minneapolis, Minn.	1918	18	6	?	J. A. W. W. A. Vol. 6, p. 773.
Nashua, N. H.	....	?	?	Many	J. N. E. W. W. A. Vol. 24, p. 382.
Newburgh, N.Y.	1918	5	?	Many	An. Rpt. N. Y. St. Dept. Health, 1920.
Niagara Falls, N. Y.	1925	1	0	0	U. S. P. H. Rpt. Aug. 1925.
New Bedford, Mass.	1903	?	?	?	J. N. E. W. W. A. Vol. 17, 1903, p. 69.
Newport, Vt.	1924	16	4	?	Letter from St. Dept. Health.
Nitro, W. Va.	....	....	..	....	J. A. W. W. A. Vol. 6, p. 752.
Philadelphia, Pa.	1913	309	?	?	Engr. News, N. 20, 1913, pp. 1 022–3.
Philadelphia Navy Yard	1920	?	?	Several	E. N.-R. Vol. 84, No. 25, 1920, p. 1 187.
Piedmont, W. Va.	....	470	?	?	J. A. W. W. A. Vol. 6, p. 753.
Rochester, N. Y.	1910	58	?	?	J. A. W. W. A. 1920, Vol. 7, p. 648.

TYPHOID EPIDEMICS CAUSED BY CROSS-CONNECTIONS, AUXILIARY INTAKES AND BY-PASSES.

A. Cross-Connections (Continued).

Place.	Year.	Typhoid.		Intestinal Disturbances.	References and Remarks.
		Cases.	D'ths.		
Rockaway, N. J.	1923	41	4	?	Engr. News Vol. 91, 1923, p. 267.
Rockford, Ill.	1924–25	12	2	?	E. N-R. Vol. 94, 1925, p. 525–27.
Seneca Falls, N. Y.	1920	102	?	?	Report on File.
Sheboygan, Wis.	1925	11	0	Several	Rpt. St. Bd. Health, 1925.
Springfield, Ohio	1911	12	?	?	An. Rpt. Ohio St. Bd. Health, 1911, p. 469.
Sterling & Rock Falls, Ill.	1924	12	2	?	Ill. Dept. Public Health, Cir. No. 7, Nation's Health, June, 1925.
St. Paul, Minn.	1914	?	?	80	J. A. W. W. A. Vol. 6, p. 752.
State of Illinois	5 outbreaks		80	0 ?	Letter from H. Ferguson, Oct. 15, 1923.
Toronto, Ont.	....	5	?	?	Proc. A. W. W. A. 1913, p. 163.
Utica, N. Y.	1917	49	?	Many	An. Rpt. N. Y. St. Dept. Health, 1917.
Van Wert, Ohio	1913	33	5	600	Rpt. Ohio St. Bd. Health, 1916.
Winnepeg, Manitoba	1908	26	3	....	E. N.-R. 17: 507, 1910
Wolfpit, Ky.	1925	67	7	?	Letter from Ky. St. Bd. Health, Apr. 3, 1926.
Woonasquatucket, R. I.	1917	40	4	?	Qr. Bul. St. Dept. Health, Vol. 3, No. 4, 1917, pp. 26–30.

TYPHOID EPIDEMICS CAUSED BY CROSS-CONNECTIONS, AUXILIARY INTAKES AND BY-PASSES.

B. Auxiliary Intakes and By-Passes.

Place.	Year.	Typhoid.		Intestinal Disturbances.	References and Remarks.
		Cases.	D'ths.		
Herkimer, N. Y.	1918	155	28	?	Health News, N. Y. St. Dept. 1920.
Moline, Ill.	1918	125	24	?	Data by Mr. Ferguson, Ill.
Milwaukee, Wis.	1916	4 500	40	5 000–6 000	St. Bd. Health Rpt. 1916.
Neenah, Wis.	1920	19	8	Few	St. Bd. Health Rpt. 1918–1920.
Schenectady, N. Y.	1900	53	3	?	.....
Tonawanda, N. Y.	1919	236	?	?	J. A. W. W. A. Vol. 7, 176–8, Mar. 20; Can. Engr. 38; 439, May 6, 1920.
Charleston, Ill.	1925	0	0	3 000	Data by Mr. Ferguson, Ill. (By-pass existed, epidemic by inadequate filtration and failure to chlorinate.)

Note by N. E. W. W. A. Committee:
The possibility of error in the above Table should be noted. In the case of Auburn, N.Y. and Nashua, N. H., the Table is known to be in error and some doubt exists as to accuracy in certain other instances.

APPENDIX D.

RECORD OF CHECK-VALVE TESTS AT NEW BEDFORD, MASS.

Summary January, 1927.

Number of Plants having check-valves on City connections	54
Total number of sets of double checks in service, Jan. 1, 1927	81

Classification as to make:

Chapman	52 Sets
Fairbanks	12 „
Pratt-Cady	7 „
G.F.E.	6 „
Ludlow	4 „
Total	81 „

Classification as to Size:

6-in	28 Sets
8 „	41 „
10 „	12 „
Total	81 „

Date Installed:	No. of Sets.	Years in Service.	Valve Years.
1910	3	16	48
1911	4	15	60
1912	13	14	182
1913	20	13	260
1914	4	12	48
1915	23	11	253
1916	4	10	40
1917	4	9	36
1920	2	6	12
1921	2	5	10
1925	1	1	1
1926	1	..	..
Total	81		950

Period of Service:

Minimum	0 Yrs.
Average	11.7 „
Maximum	16.0 „

Total Number of Tests:

Total	2 152
Per set	26.5
Per set per yr. in use	2.26

Results of Tests:

Both leaking (one in 1 000)	2
One leaking (one in 94)	229
Both tight (one in 1.12)	1 921
Total	2 152

Openings for Examination:

Total	436
Per set	5.4
Per set per yr. use	.46
Once every	2.2 yrs.

Classification of Causes of Leakage:

Corrosion	8 Times
Tuberculation	127 „
Not seating	50 „
Gasket poor	36 „
Obstructions	3 „
Unstated	8 „
	232 „

NOTE:— Leak caused by mechanical defect 50/232 = 22% of times
Leak caused by tuberculation 55% of times

Repairs:

New facings total	178
New facings for each valve	178/81 × 2 = 1.1 for 11.7 yrs.
Once in every	10.6 yrs.
New clappers (soon after installation of old type Pratt-Cady)	9
New clapper arms	22
Repaired clapper arms	40 times in total time.

APPENDIX E.

RESULTS OF LATEST TESTS BY INSPECTION DEPARTMENT ASSOCIATED FACTORY MUTUAL FIRE INSURANCE COMPANIES OF SPECIAL TYPE F. M. DOUBLE CHECK-VALVES IN FACTORY MUTUAL RISKS.

	Both tight.	Outside leaky.	Inside leaky.	Both leaky.	Not tested.	Total number.
Canada	114	15	2	1*	3	135
Maine	27	2	2	0	1	32
New Hampshire	27	2	0	0	5	34
Vermont	4	1	0	0	0	5
Massachusetts	238	20	3	0	8	269
Rhode Island	16	4	0	0	0	20
Connecticut	114	2	1	0	7	124
New York	120	25	9	1†	4	159
New Jersey	52	8	2	1‡	2	65
Pennsylvania	27	3	1	0	5	36
Delaware	1	1	0	0	0	2
Maryland	2	1	0	0	0	3
Virginia	9	2	0	0	0	11
West Virginia	1	0	0	0	0	1
Ohio	17	1	1	0	3	22
Kentucky	1	0	0	0	0	1
Indiana	11	0	3	0	0	14
Michigan	7	3	0	0	1	11
Minnesota	1	0	0	0	0	1
Wisconsin	14	0	0	1§	0	15
Illinois	10	0	0	0	5	15
Iowa	1	0	0	0	0	1
Missouri	2	0	2	0	0	4
North Carolina	5	5	1	0	0	11
South Carolina	3	1	0	0	0	4
Georgia	0	2	2	0	2	6
Tennessee	2	0	0	0	1	3
Alabama	4	0	2	0	1	7
Louisiana	0	0	1	0	0	1
Total Sets						1 032

*Secondary supply from cistern. New rubber facings appear to be necessary. Mill promised immediate attention.
†Cleaning had been neglected. Cleaned at once by mill mechanics who reported both left tight.
‡Cause unknown. Being corrected by mill.
§Cleaning had been neglected. Being corrected by mill.

When a valve is classed as leaky it does not mean that water was passing back through the valve, but that, if the pressure on the downstream side of the clapper were raised above that on the other side, water might pass through that particular valve but not through the set as a whole.

Valves listed as not tested are practically all new installations that have not as yet been provided with testing facilities.

May 2, 1927.

APPENDIX F.

RESULTS OF TESTS OF DOUBLE CHECK-VALVES BY CONNECTICUT STATE DEPARTMENT OF HEALTH DURING 1927.

Iron-Body Valves.

Number of tests	624
Outside check only leaking	17
Inside check only leaking	7
Both checks leaking	1*
Both checks O.K	599
Tests O.K. on second try	4†

All-Bronze Valves.

Number of tests	273
Outside check only leaking	3
Inside check only leaking	0
Both checks leaking	0
Both checks O.K.	270
Tests O.K. on second try	0

*This leaking installation was inspected by the manufacturers of the check-valves, who found the cause to be unevenness in the flat rubber facings.

†Counted O.K. because of the likelihood that any flow through the pipe would flush out sediment noted under quiescent conditions. These might be considered as leaking in one valve.

Discussion.

Frank A. Barbour.* For some time back I have thought that water-works men generally had reached a firm conclusion against all connections between public and non-potable private supplies, and I have listened to Mr. Weston's report, or the digest of the report, with considerable surprise. Certainly,— if the 45 pages of the report are in line with the digest — I cannot see how anyone, responsible for furnishing safe water at all times to consumers, can do otherwise than vote against the resolutions.

To my mind, any apparent approval of cross-connections by this Association — however qualified — would be a step in the wrong direction. We spend much money in the purchase of land for the protection of supplies, for purification plants, for laboratory control, for provision of the various lines of defense against pollution, and to recommend for adoption resolutions certifying as reasonable practice under certain conditions the running of the risk of introducing a slug of polluted water directly into the distribution system through cross-connections with polluted supplies — however much such risks may be minimized by improved design — is, to my mind, all wrong, and I am against it.

It may be reasonably safe for New Bedford, with its standard of supervision and maintenance, to permit double check-valve cross-connections, but for this Association to take a position that may be construed as approving such practice as good doctrine would be about the greatest mistake we could make. Always we should remember how any pronouncement of this Association may affect practice in the general run of water-works plants, in many of which the standard of supervision is not of the highest. To the men in charge of these works the dictum of this Association will be, in many cases, law and gospel, and any position taken in reference to cross-connections should be incapable of abuse or misinterpretation — a fundamental condition that the resolutions offered fail to meet.

Thus, in paragraph 2 the Committee recommends that all cross-connections that can be abolished "without undue fire hazard to life and property" be immediately eliminated. Who is to measure what is "undue fire hazard"? Again, note in paragraph 3, the recommendation of the improved type of double check-valves "where local conditions indicate the need of such connections." Who is to determine the relative need? In paragraph 5 double check-valves are condemned where the secondary supply is of such raw-water quality that it cannot be made safe by treatment. What will this proviso mean to the commissioners of the average run of water-works plants?

In short, the resolutions, if adopted, with their qualifying adjectives,

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will leave the problem of cross-connections wide open for abuse and, in my opinion, the result will be a marked increase immediately in double check-valve installations — many of them in places where inspection would probably be inadequate for safety.

Undoubtedly the double check-valve equipment now proposed is an improvement over that used in the past, but this latest arrangement has not been in service long enough to test its safety, and quite probably ten years from now we may have costly evidence of failure, with the result that something else will then be offered by the insurance men. Such failures will occur, not because of the design of the connection, but from careless or incompetent inspection which — so long as the personal equation enters into water-works service — must be given controlling weight.

The cross-connection problem, from the standpoint of this Association, hangs on the fact that as water-works men our prime responsibility is protection of the consumer by furnishing a supply, safe beyond question at all times and also adequate for general fire service. If there are questions involved as to the relative value to a particular community of providing the additional fire service made possible by cross-connections, as compared with the risk entailed by such connections — let the local authorities take these risks, without the support of resolutions by this Association which, as a yardstick in measuring these local conditions, would be of no value. In other words, as an Association we should strive for the ideal in protection of the consumer and in doing this we should keep our efforts in balance and, while advocating all possible safeguards in protection and purification of supplies, should not apparently countenance risks immediately adjacent to the consumer.

The Chairman. Mr. Barbour did not take up one subject that I had hoped he would. The argument arose in one of our committee meetings as to just what responsibility a municipality has in supplying an adequate water supply. In other words, the municipality invites a considerable investment in the community. Should it supply an adequate water supply to replace emergency supplies through check-valves?

Mr. Barbour. From the standpoint of the insurance men, the question involved is not simply a reinforcement or duplication of the distribution system, but rather the providing of a complete independent secondary source, and this would not appear to be economically possible, except under very unusual conditions. In this respect, I do not understand why the Committee so emphasizes this obviously impracticable method of avoiding cross-connections as to place it in the first paragraph of the resolutions.

In my opinion, the first and fundamental statement should be a straight condemnation of all cross-connections, in line with the American Water Works Association, and many State Departments of Health. It is to be remembered that the position taken by this Association has no legal standard in the premises and — no matter how high the standard of consumer protection is set, there will always be departures from the ideal by local

authorities, but let us stick to the water-works side of the case. There need be no misgiving but that, in any particular problem, the arguments in favor of cross-connections will be well extended by the industrial interests, and particularly by the insurance men, who are always on the job, and whom I congratulate for the good work, from their standpoint, they have apparently been able to do in the Committee.

The entire report of the Committee has not been available to me, but in the digest the absence of any statistics demonstrating from experience the relative risk of trusting to the public supply for sprinkler service or the average cost of providing an open tank-connection between the public and private supplies, is outstanding.

Let me measure the effect of the proposed resolutions by brief reference to a pending problem in cross-connections. A small town has recently constructed a water system costing one-half million dollars, largely due to the development of a supply of unusual purity at a distance of some six miles. In that town there is an industrial plant the valuation of which approximates two-thirds of the total valuation of the town. This plant, which takes a secondary supply from a highly polluted river, but which, by purification, could be made safe, now desires a double check-valve cross-connection between its supply and the town system. At no great expense an elevated tank can be provided for connection between the two supplies, without danger of back-flow, but the cross-connection has been requested. The water commissioners have a high regard for any doctrine set forth by this Association. What may be the effect of such resolutions as are proposed for adoption? How can these commissioners measure the relative necessity of the cross-connection or of the risk entailed in such connections? Clearly, their predilection to oppose any connection should be supported and not weakened by any action of this Association. Clearly, also, the resolutions proposed would supply much ammunition for those desiring the cross-connection.

CALEB M. SAVILLE.* I concur without reservation in all that my friend, Mr. Barbour, has said in his comments on the report of the Committee on Cross-Connections and wish to be registered as opposed to the passage of the resolution submitted by the Committee.

I believe that it is not proper for the NEW ENGLAND WATER WORKS ASSOCIATION to go on record as favoring such a resolution, and that this Association of water-supply men is forfeiting its right to the high opinion in which it is now held in public and professional circles as a leader in the fight for safe water supply, if it shows a disposition to compromise with public health by truckling to a few enthusiasts that are willing to take a chance with public health in order to obtain a few dollars in premiums — blood money.

By "safe water supply," I include fire protection as well as domestic service, for there are other methods than cross-connections with a polluted

*Manager and Chief Engineer, Hartford (Conn.) Water Works.

source to provide fire protection satisfactory to the majority of fire insurance interests.

If there are any local circumstances that permit of some deviation from the strict rules for health protection, they can well be considered as they arise by state health authorities, where the burden of a mistake can be definitely placed rather than opening the door to a few zealots to bring pressure on a local water department under guise of following out the recommendations of a nationally recognized association of water-works operatives.

The NEW ENGLAND WATER WORKS ASSOCIATION was founded by water-supply men for the purpose of giving to water consumers the best obtainable water and water service. When equal fire protection can be obtained without even remote danger to public health, *best* water service is not obtained.

In the past, the record of this Association has been without a blot in going the limit to safeguard public health.

It is a breach of faith with such outstanding members of this Association as Stearns, FitzGerald, Whipple, Sedgwick and others, for this Association to consider compromise with commercial interests when there is even a suspicion of danger, remote though it be.

The hand which offers this compromise "is the hand of Esau, but the voice is the voice of Jacob," and the NEW ENGLAND WATER WORKS ASSOCIATION can ill afford to exchange its birthright for the mess of pottage which has for one of its ingredients, compromise with public health.

The very fact that this report admits the need of "proper installation and supervision" should be a sufficient cause for rejection by public health proponents of a recommendation that would favor any connection with a polluted source of water supply.

I do not know what would be the attitude of the United States Public Health Service toward the use by public carriers of water that was obtained from a supply over which hangs the threat of a dose of highly polluted water prevented from entering the public supply only by successful operation at all times of a man-made automatic contrivance. In view of their somewhat strict rules in other respects, it would seem hardly probable that they would look on such connections with equanimity, especially when the risk is undertaken to favor a small insurance group or save a few dollars in insurance rates.

This Association is primarily one for water-supply men, not insurance men or material men, and in the almost universal understanding of the term, "public water supply" means a supply of potable water. It is a very specious argument to interject the need for water supply to prevent fire and thus protect life.

There are other means of accomplishing fire protection without jeopardizing human life. Stripped of plausible, but unessential words, the only argument vouchsafed in this report which is recommended for approval by

this Association, is that a combination of potable and polluted water will save a few dollars in insurance rates.

Do you, Mr. Water-Works Superintendent, for one moment suppose that in case of an epidemic of water-borne disease due to a defective automatic contrivance, your public would absolve you from blame because the insurance company recommended cross-connections even if they were governed by the *best valves obtainable*?

A calamity cannot be excused as an "Act of God" unless every human precaution has been taken to prevent it, and leaving the door open a crack only does not minimize responsibility.

I believe this Association should go on record in stating what it believes to be the proper way to safeguard a public water supply. What individual towns and the states do, is not of the responsibility of this Association, but this Association cannot afford in any way whatsoever to compromise with the health of the people.

Far be it from me to intimate even that political exigencies prevent water-department superintendents from putting money into their water-works plants if they can get a factory owner to put in a pump that will help out in time of need, by pumping dirty and polluted water into the public water mains.

The Committee is very much to be congratulated that it had a unanimous report with all of the divergent views and powerful insurance interests that were represented on the Committee. However, oil and water will not mix and engineers who are interested in public health cannot justify compromise with engineers who are interested in property.

As to the insurance attitude on this matter, all that is wanted by the general insurance interests is secondary protection. There is only a very small group — this Boston group of mutual fire underwriters — who are interested in the check-valves; that is, in check-valves by themselves. The other members of the mutual factory insurance associations and the stock companies want fire protection only, they do not urge double check-valves. They give credit to double check-valves if they are installed. They do not urge them, and in fact, whenever possible, they speak against them.

I hope that this Association will not compromise in this matter, but will take definite and unmistakable action to put itself on record as opposed to cross-connections and recommend that there shall be no more installations of this kind. The Connecticut State Board of Health has made such a ruling, and it is a very wise and good one. The New York State Department of Health has stuck to its guns in spite of the tremendous pressure put upon it by the same group of factory insurance sellers and has affirmed its decision against the check-valve menace. After, I think it was, 1926, there were to be no more installations of double check-valves in Connecticut. Those that were there were to be eliminated as fast as possible.

The Hartford Water Board several years ago, much to the distress and disgust of these same factory mutual interests, passed a vote that there

should be no more double check-valve connections, and what there were should be taken out. We had the utmost coöperation with the manufacturers after the vote was passed. Before that they came before the Board and did their utmost to save the checks, but, after the hearing, when the Board voted to take out the valves, because its members individually did not care to assume any responsibility for failure to protect the public water supply, every one of the factory owners faithfully and readily complied, and we have had not only no trouble but loyal coöperation since.

On the other hand, the Hartford Board of Water Commissioners has done everything in its power to improve its system. It has duplicated supply mains and put in large mains, valves, hydrants and connections and is continually on the move to do something of that kind. The result is that Hartford has the highest insurance rating in the country.

Mr. Scott spoke of the swing connection. For an emergency perhaps, that is as good as anything that can be had if a concession to local interests is desirable. In Hartford, we have several of them, but in Hartford we have, so far as we know, no physical connection with any dual supply. An inspection by the Water Department is made through the factories in Hartford once every month. We sometimes find these swing connections in place when they have been used and left. Where we find them so connected, the owner is warned. If that owner forgets again to take down the connections after use, he is warned that his supply will be shut off on a repetition of the offence.

I hope that this resolution will not pass, and I hope that in its present form, it will be killed. I hope that this Association will go on record as being opposed to any physical connection between a public water supply and any supply that is unfit for domestic consumption.

I feel that it is unnecessary and undesirable to comment on the several sections of this report in detail, as in my opinion, all of its provisions are tainted with insurance propaganda.

I hope that as a whole, it will be received, and so handled in a parliamentary way that it cannot again be brought before this Association.

In place of this report and recommendation, much as I dislike that this Association should be a follower, I hope that the NEW ENGLAND WATER WORKS ASSOCIATION will see its way clear to unmistakably assume as its standard, the position already taken by the organization of State Sanitary Engineers and the American Water Works Association, who unequivocally and without play upon words, have stated that they are opposed to any physical connection between a potable public water supply and another which cannot so be classified.

GEORGE F. MERRILL.* There is one feature of cross-connections that perhaps has not been fully brought out.

In some small mill towns where the fire supply is interconnected with the water supply, there are arrangements whereby the mill fire supply

*Ware, Mass.

can be connected with the water-works system by opening a gate-valve. It seems to me that this procedure is almost criminal unless means are provided to sterilize the mill water before it gets into the town mains. In some places interconnection is accomplished by taking the clappers out of the check-valves in case of emergency. It seems to me that this goes beyond reason.

STEPHEN DEM. GAGE.* The type of cross-connection that Mr. Merrill has referred to is more or less common in many small mill villages where the factory owners have installed a drinking-water supply in the plant and have then carried this supply outside to serve mill tenements. In some instances, this water system has been incorporated as a separate water company in order that business and residential property not owned by the factory may be served with water. The mains in these systems are usually small and the capacity of the well from which the supply is obtained is generally sufficient only to take care of ordinary domestic uses, with no reserve for fire fighting. It is quite common in these small factory-owned supplies to provide a cross-connection by which an auxiliary supply from the factory fire pumps may be turned into the mains in case of a fire in the village.

During a fire the mains are likely to be filled with a water that is not safe for drinking. Even if the mains are thoroughly flushed immediately after a fire, as is the usual practice, there is some danger that polluted water may be left in dead-ends or service piping. In addition there may also be danger through leakage of non-potable water through the gate separating the two supplies. In one installation of this type in Rhode Island, the cross-connection is protected against leakage by two hand-operated gates with a dry pipe between. The open end of the dry pipe is located in the mill beside a walk over which mill officials pass frequently, where, therefore, any leakage through either gate would be detected immediately. To prevent tampering, the two gate-wheels are tied together in closed position by a leather belt fastened with a padlock. In case of fire in the village the belt can be cut and the gates opened without waiting to find the key. To my mind this constitutes about as thorough protection against leakage as can be devised to meet this particular situation.

In the case that I have described the elimination of the connection with the factory pumps would leave the village without adequate fire service and might lead to a conflagration causing not only a large financial loss, but much suffering and perhaps loss of life. In other cases, the entire life of a community is centered about a single industry, the loss of which would spell disaster to the community. In such a case the elimination of the cross-connection through which the factory obtains necessary fire protection from the public water supply may create a financial and social hazard that would be more important to the people than the potential danger to health. In still other cases a large proportion of the operating revenue of

*Chemist and Sanitary Engineer, Rhode Island State Board of Health.

a public water supply may be derived from a single industry or group of industries, and a heavy fire loss to the industry might seriously cripple the operation of the water works. Here any increased fire risk to the industry would also become a potential danger that might affect the proper operation and development of the public water supply.

The public-health or water-works official who is called upon to make a decision in relation to the elimination of cross-connections is up against a difficult proposition if he would be fair to all parties concerned. Potentially, all cross-connections between a potable and a non-potable water supply are dangerous, and from a public-health viewpoint should be eliminated. On the other hand, such an elimination may introduce other hazards that outweigh the health hazard, when the welfare of the community as a whole is considered. In practice then the decision calls for a careful balancing of all the factors and risks in each individual case, and any attempt to make a rule-of-thumb application of an arbitrary regulation is sure to be detrimental to the public interest at times.

There is one thought which Mr. Merrill has introduced that is worthy of more thorough study. That is that we might sterilize these cross-connected non-potable supplies and thereby eliminate the health hazard of the cross-connection. This thought occurred to me some time ago, and I discussed it with representatives of firms making chlorine-disinfection apparatus. What is needed is a type of apparatus that can be relied upon to automatically begin chlorinating the water when the fire pumps are started and to continue in operation as long as those pumps are in action. Unfortunately, none of the types of chlorinators now on the market appears to fulfil these special requirements, but there should be no insurmountable difficulty in designing and manufacturing such apparatus. If we could add a sufficient dose of chlorine to sterilize the water and also to make it unpalatable for drinking, we would largely reduce and perhaps eliminate the health risk in those cases where cross-connected supplies seem to be necessary.

JOHN O. TABER, JR.* I have listened to the speakers with great interest, and it has occurred to me, speaking as a water-works man, that Mr. Barbour has put a hypothetical case before us where the water supply of a community may indirectly receive pollution from a neighboring community. It seems to me that the water-supply problem, for most of our communities in this Commonwealth, has been pretty carefully supervised, and I should allow from what I have heard that there is a slim chance of pollution from these cross-connections. I will, however, allow that it should be taken care of.

It seems to me that the problem is not presented in its entirety unless there is coupled with it treatment for the potential source of pollution. But what is being done about that? Isn't it true that if the same effort were directed to stream protection that is put into the water-works prob-

*Superintendent of Public Works, Attleboro, Mass.

lems that we have here, the ratio of hazard would be reduced in a considerable degree? At this point I would like to ask, whether Mr. Goodnough would be good enough to tell us just how far we can go in Massachusetts under the General Laws and special laws of this Commonwealth in enforcing positive regulations against stream pollution and pond pollution, or any other auxiliary source that might be used in this cross-connection question. To me both problems interlock, and I can't see how we can solve one satisfactorily without taking cognizance of the other.

X. H. GOODNOUGH.* In this State the decisions of the courts are that every man on a river has a right to have the water come to him in the same condition it comes to the man above him. That is theoretical. Practically the courts have said that each man is entitled to reasonable use of the water. And the result is that the State Department of Health has made efforts to keep the rivers as clean as possible, and the Legislature has often refused to allow the discharge of sewage into rivers where it ought to be treated. But there are a few cases where the State — I think there are three where the State has said that all pollution of the river is prohibited. Now, that is all right for the State to say so, but it is a very difficult thing to accomplish it. We have tried it in one river and we find it is absolutely impossible to do it without driving the factories and the towns out. It can be done by long lines of sewers along these valleys. There are two such systems now under consideration,—one following the length of the Neponset River, which is now before the Legislature, and another for the length of the Merrimac River, which is also before the Legislature.

HENRY V. MACKSEY.† I have listened with considerable interest to the previous speakers, and can agree to a certain extent with all of them. I do not think that at this time we should drag in the question of stream pollution. This Committee had enough of a load to carry trying to solve the cross-connection problem without attempting to regulate the pollution of all the streams within the State.

I can quite understand the position of Mr. Barbour, who gives all that is in him when he builds a water system and provides pure water for a town, and is then told that, because it is necessary for fire protection, that system may be polluted at any time. Yet when we speak of the NEW ENGLAND WATER WORKS ASSOCIATION standing out rigidly in favor of a potable water supply without taking any chances whatever in order to provide fire protection, I am sure we are asking the water plant and the water commissioners and the authorities of the various cities and towns to undertake a load that they cannot carry. No water system is built, in my opinion, that is so thoroughly guarded that there may not be some pollution, even though all the water is filtered. We take certain risks at all times, and I think it is necessary that we take some risk in order to give fire protection.

*Chief Engineer, Mass. State Department of Health.
†Framingham Centre, Mass.

I am quite in accord, however, with the previous speakers that the men who represent the underwriters bear too heavily on fire protection, and they are so anxious to have fire protection that they are willing to overlook the main object for which the water system was built. In almost all of these fire-protection systems they can use sprinklers and do use them; and they can take reasonable amounts of water and make their sprinkler systems effective. But do they? No. Their idea seems to be to help equipment companies to sell all the sprinklers they can, to sell all the piping they can, and consequently to make the largest connections they can with the system. In return they try to give the property owner a reduction in his insurance rate, which is practically the only thing he gets. His opinion as to whether the property may be safe or may not be safe is of no account. Decision is left in the hands of the engineers for the underwriters. All he gets out of it is a lower insurance rate. It is a case of hold-up. He needs that low insurance rate and he agrees to anything to get it.

It may be that the wording of this resolution as offered to us is a little bit unfortunate, and I think it is a mistake to say that this Association goes flatfooted against cross-connections under any and all circumstances.

HENRY A. SYMONDS.* We appear to have advanced rapidly in determining the status of cross-connections. It was not a great many years ago when I first heard this matter brought before the Association by Mr. Saville, and his suggestion that we should do away with cross-connections as fast as possible seemed, then, extremely drastic.

There is one point of the report that I think has not been touched upon in the discussion. It is that the recommendation which would place the authority governing cross-connections with the State seems to me rather fortunate. It has been suggested that the question of what cross-connections shall be permitted and to what extent provisions suggested by the Association shall be carried out would be in the hands of the town authorities. Now, that does not seem to me the proper way.

The authority to determine what should be done regarding cross-connections should not come from the water departments or water companies but from some higher authority. Throughout New England we have a great many communities supplied by water companies, and in these cases the interest of the water companies as against possible trouble that may come from cross-connections is really in conflict. The community has very little to do with it as a rule except in very gross cases.

If the control of cross-connections is left with the local authorities either departments or companies, there is certain to be very imperfect execution. The influence of large interests, who frequently are large taxpayers and hold the balance of power in the towns, as well as the personal interests of the water-works officials, will conspire to interfere and nullify the intent of the suggested regulations. Even if the main purpose is ac-

*Consulting Engineer, Boston, Mass.

complished, enforcement would be, in many cases, a matter of perplexity and embarrassment to the officials in charge.

State authority will be readily respected and State laws or mandatory regulations of the State Department of Health will be complied with without the personal element which local regulations introduce.

I am speaking from a knowledge of a number of cases of this kind where it has been very hard for the water companies to know just what they should do.

PATRICK GEAR.* This matter reminds me somewhat of the city government trying to decide upon a budget when all the various departments are trying to obtain a lot of money with nobody to look after the taxpayers' interests, except the mayor and the finance committee, who attempt to head them off and pare them down a little. But no such guardians are here today; there is nobody here looking out for the manufacturer; he was not notified.

If we adopt this resolution that we have here, we have to go back to the manufacturer and tell him that he has got to have another supply of water. God knows he has enough to do now to get along as he is, trying to make both ends meet, and he is trying to get out of business as fast as he can and put his money into the insurance business or the banking business, — the only two things that are making any money today.

We have been told that four or five sprinklers always put out a fire. A 2-in. pipe will supply that many sprinklers; but the insurance people insist on a 6-in. pipe. I think there are one or two cities that will give them only a 4-in. — I wish we could do it. But they generally insist on a 6-in. or bigger.

Now, about the double check-valve. The manufacturers are not all willing to coöperate with us by putting in the double check-valve. A double check-valve costs close onto $1 000, and when a manufacturer has five or six connections going into the plant, such as the insurance people say he has to have, there is $4 000 or $5 000 put into check-valves.

Now, we all say that we are interested in health. We are more interested in money, a good deal, than we are in health. You will remember that a couple of years ago there was a decision handed down by the Court in Dedham in which a man got a verdict for several million dollars. At the time this man got the award he was sick. He had to be taken South to be returned to health. If the doctor who brought him back to health had charged him $25 000, the doctor would have been said to be a robber. That shows that money is worth more than your health any time.

The manufacturers in this State today are having a hard time to get along. Every insurance concern in the country today is making millions of dollars but they tell you they are not.

You tell any manufacturer that he is making money today and he will deny it. We can go back and tell them that they can have another supply

*Superintendent, Holyoke (Mass.) Water Works.

of water, that they can have the double check-valves, but it all means money for them to get them.

I am in favor of the report, but I do not want to go home and say I voted for this report and then to turn around and say that we will take our time about doing it. We are all willing to help out and get the double check-valve, but the secondary supply is going to cost money. It will bankrupt some concerns I know if they have to put in a secondary supply of water.

EDWARD V. FRENCH.* I think we have all been much interested in the points that have been brought out. I am sure everyone here has great respect for any opinion that Mr. Barbour or Mr. Saville expresses. We know the standing they have and the work they do.

There are two or three points that I think would help greatly if we could get them before us at this time. The first thing that we may well appreciate is that water supplies have a dual purpose. As water-works men, there is the duty to supply good water for domestic purposes and manufacturing uses, and ample water for fire purposes. These uses must be combined. The province of the water-works man does not stop when he simply furnishes potable water. We all know, nobody better than Mr. Barbour, that the costs of our water systems have been much increased by the large capacity necessary to furnish water for fire fighting. It would not be reasonable action after spending this, to deny the use of our public water supplies for fire purposes and to deny the use of them in the way which has proved the most efficient ever developed, namely, through the automatic sprinkler supplied from two independent sources, so that at the *instant* fire occurs, water in ample volume will be *always* available.

This is not a simple question of conflicting interests. I want to make one thing clear — that although I represent certain of the Factory Mutual Companies, we are not insurance people primarily. We are really engineers for the manufacturers of New England and other states, making a specialty of studying fire protection just as Mr. Barbour and Mr. Saville study their branches of engineering.

Today fire-protection work has become a definite branch of engineering. Throughout the country and in this State particularly, a large number of leading manufacturers are working together to study the fire problem and they act through the Factory Mutual Companies. They are not primarily in the insurance business. Their main purpose is to study fire hazards and to do their part in reducing the tremendous fire waste which is a disgrace to our country. This work began many years ago with the aim to seek causes of fires, provide reasonable remedies and thereby actually prevent losses which the manufacturers felt was a more valuable work than simply distributing them through insurance. This work has become a useful branch of engineering and these efforts, which had their start nearly one

*President, Arkwright Mutual Fire Insurance Company, Boston, Mass.

hundred years ago, have resulted in the development of the present standards of fire protection.

The automatic sprinkler has been the most important single factor and this is so because sprinklers guard every point and, when given an ample and never failing supply of water, are ready to meet any contingency.

I conceive it to be the duty of this Association to take a broad view of any such vital matter. I think I can speak perhaps with some fairness for I have been a member of this Association for many years, and it seems in every way desirable that the full function of public water supplies should be recognized clearly and also the economic conditions, particularly as these are today affecting many of the manufacturers of New England. We have simply endeavored to coördinate these factors in a fair spirit, feeling that they need not clash and that it is our duty to find the most reasonable way to combine the several functions of public water systems in a safe and proper manner and without endangering anybody. This is the position that, it seems to me, the Association should take and, in doing this, lead definitely toward high standards in water-works practice as to safety of water and the development of the best fire protection.

Let us divest ourselves from any feeling that we are pleading for special interests, and realize that what the manufacturers want when we get down to it, are simply fair conditions. They wish to do nothing that endangers public health. They wish in every way to conform to all reasonable restrictions and provisions to make their use of water for fire protection such that it does not endanger anybody. After a good deal of study and many years of experience, the method of protecting cross-connections for fire purposes through special double check-valves, as has been described, has been brought to the state of perfection that those who have spoken previously and from a long experience have told us about.

With this statement of general conditions, I believe the report proposed will make a definite stride forward in handling this whole matter. It points out the possible dangers. It says that it is desirable to eliminate these in every possible place by prohibiting every cross-connection that has not some thoroughly good reason for its existence, and it proposes that this work shall go on progressively so that these cross-connections, instead of increasing, will very definitely decrease as years go on, if the advice of this Committee is taken. It then says that in those cases where the fire hazard would be increased by the abolition of cross-connections, where an excellent system of fire protection built up through long years of study, would be impaired seriously,— that for the present, until some duplicate or secondary water supplies can be provided, or perhaps some better method of protection devised, this finely developed and perfected double check-valve arrangement, may be permitted, but only permitted where it can be installed in the best manner and where it will be under the most effective supervision. Such cases will be relatively few in New England and reduced to this small limit and under these conditions, the chance of any dangerous pollution

occurring is reduced below that existing at many other points in our water-works systems and is brought well within the point of proper control.

This Association now has opportunity to make a reasonable weighing of all these factors, and it is desirable to avoid any extreme position and make an effort to see the whole thing in all its phases — health, economy, business, and other elements — balancing them fairly, giving each its proper weight and looking at the whole thing in a broad and comprehensive way. Thus the Association may point out the best and most reasonable course for the handling of this important matter.

M. N. BAKER.* I have been a member of this Association for many years and have taken great pride and satisfaction in it as a leader in the water-works field.

I shall be bitterly disappointed if the Association takes a back seat as compared with the American Water Works Association and the Conference of State Sanitary Engineers in this matter of abolition of cross-connections. The State Sanitary Engineers, after committee work for several years, were the first to adopt resolutions against cross-connections way back in 1921. Then the American Water Works Association, first through its Technical Division in 1925 and then by action of the full association in 1926, did the same. It comes to me as a great surprise that the NEW ENGLAND WATER WORKS ASSOCIATION, which I have always regarded as a leader, should take a secondary position on such an important matter as this, and put out resolutions which, while I appreciate the difficulty under which the Committee has labored, are evidently the result of compromise in order to get a unanimous report and resolution. I would much rather have seen a majority report and a minority report put in.

This is essentially an Association of water-works men. We are interested in the water works of the country, and we are interested in the public health of the country. If the insurance people have conflicting interests let them work through their own associations and organizations and take such action as they may, but let this Association follow the lines of the American Water Works Association and the State Sanitary Engineers in taking a strong stand for public health.

I am somewhat at a loss to understand the exact significance of the resolutions with all their qualifying adjectives and clauses. To my mind they give the insurance interests and manufacturers of any community a chance to interpret the resolutions in favor of fire rather than health protection.

At the Annual Meeting last September I expressed the hope that the Committee would make some study of the effect of the abolition of cross-connections on the unit cost of factory or mill products so it might be known just how significant or insignificant this might be. This does not appear to have been done.

The Committee Report represents as uncertain the final position of

*Associate Editor, *Engineering News-Record*, New York, N. Y.

the New York State Department of Health on cross-connections. I have just received a letter from Mr. Holmquist, the head of the Division of Sanitation, inclosing resolutions of the New York Public Health Council of February 23 of this year, in which the Council stands by the position it had already taken for the abolition by July 1, 1928, of even those cross-connections protected by double check-valves — all others were ordered out some time ago.

There is much to be said in favor of postponing action on the resolutions submitted by our Committee. Only a small percentage of the membership of the Association is here. Those of us who are here have had no opportunity to study the resolutions; none of us have had a chance to see the report as a whole. It might be advantageous to have the report printed for the benefit of the entire membership of the Association and then have it come up for final action at the Montreal convention in September of this year.

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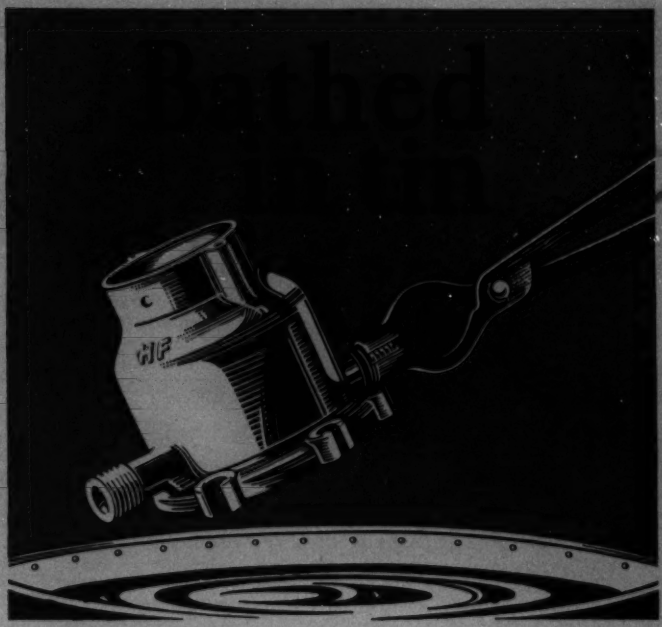

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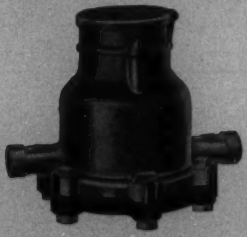

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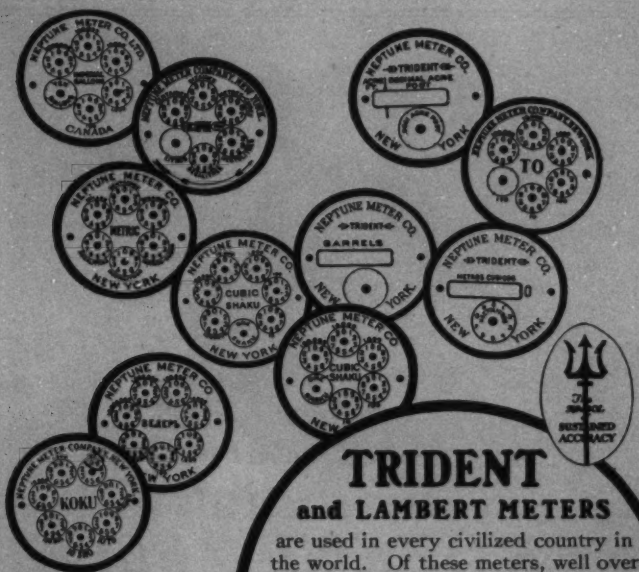

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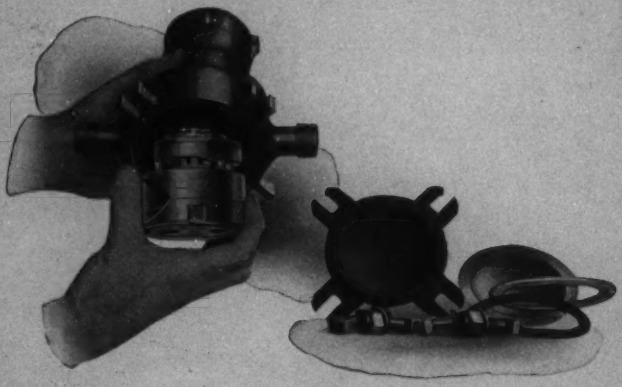

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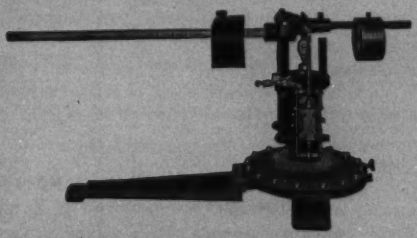

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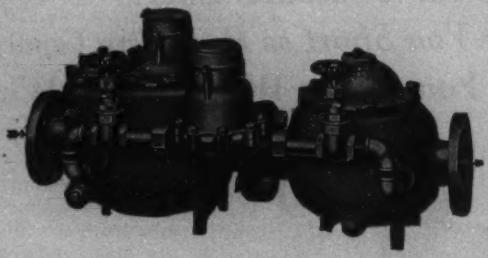

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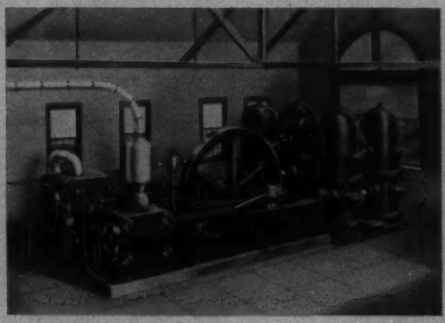

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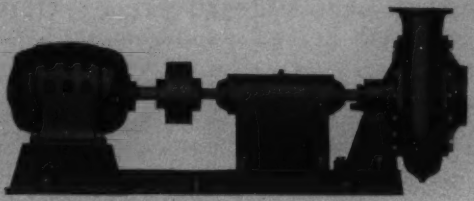

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Now a great advance in sewage pumping

For the first time a pump has been designed that will handle fluids containing the fibrous and stringy matter found in sewage — without clogging, without preliminary screening, and without the excessive power consumption that characterizes the less satisfactory open impeller type of pump.

The secret of this pump's success lies in the design of the simple two-blade impeller. The blades of the impeller have well-rounded entering ends and are well filleted with the shrouds or sides. Thus a rag or other trash does not find sharp projections on which to catch and cause clogging. Since the impeller is the enclosed type, foreign matter, in passing through, does not come into contact with stationary side plates, but is promptly discharged through one of the large ports into the pump case. In this way power is conserved and efficiency increased.

This pump was designed by Mr. A. B. Wood who has been serving the city of New Orleans and other municipalities in the capacity of consulting engineer. It was originated by Mr. Wood to cope with the very unusual sewage problems found in New Orleans and met with immediate success.

Fairbanks-Morse Trash Pumps are made in two types, horizontal and vertical. They are ruggedly built to cope with severe service and at the same time they possess such refinements as ball bearings, smoothed fluid passages, and other marks of quality construction.

Ask for bulletins giving complete details.

FAIRBANKS, MORSE & CO., Chicago

28 branches in principal cities at your service.

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PUMPS · DIESEL ENGINES · MOTORS

DE LAVAL

CENTRIFUGAL PUMPING EQUIPMENT

is the accepted standard for

MUNICIPAL WATER WORKS

WESTERN AVENUE PUMPING STATION, CHICAGO.

The largest Municipal steam turbine driven centrifugal pumping unit in the world delivering 75 million gallons per day against 150 feet head.
City of Chicago has fourteen large DE LAVAL pumping units.

TYPICAL NEW ENGLAND INSTALLATION

MILLVALE STATION, HAVERHILL, MASS.

New 7 million DE LAVAL motor-driven pump including the furnishing and erection of transformers and switchboard equipment. On test after installation this pump delivered water at rate of 7,800,000 gallons per day. Another DE LAVAL unit is on order for Kenoza Station, Haverhill.

Recent DE LAVAL municipal water works contracts include New England installations at Canton, Mass., and Millis, Mass.

Ask for De Laval Publication.

TURBINE EQUIPMENT CO. of NEW ENGLAND
CHAMBER OF COMMERCE BUILDING
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NEW ENGLAND REPRESENTATIVE FOR

DE LAVAL STEAM TURBINE COMPANY
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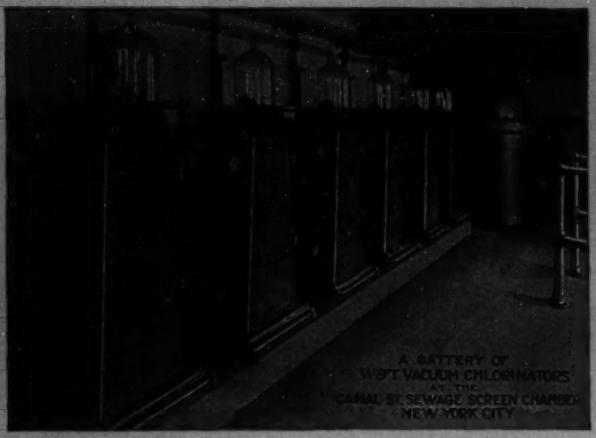

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The W & T Vacuum Chlorinator

LONG LIFE
The first vacuum chlorinator is still in operation.

ACCURATE
Indicates the true chlorine flow —average error negligible.

SIMPLE
No diaphragm valves on the chlorine supply.

LEAK PROOF
Any leaks would be *into* the apparatus — because of the vacuum.

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Silver — platinum — glass — hard rubber — nothing else comes in contact with wet chlorine.

VISIBLE CONTROL
The glass bell jar lets you see what is going on.

LOW UP-KEEP
Averages less than 1% per year.

EFFICIENT
The vacuum completely empties the chlorine cylinders.

Write for Techinical Publication No. 38N

"The only safe water is a sterilized water"

WALLACE & TIERNAN
COMPANY, INCORPORATED
NEWARK : NEW JERSEY

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For highly colored waters, especially those requiring addition of alkali, Sodium Aluminate is decidedly economical. Coagulation usually takes place at a higher alkalinity, resulting in less free carbonic acid. A smaller amount of sulphate is added to the water, resulting in lessened mineral content.

We shall be glad to investigate the applicability of Sodium Aluminate to your water supply.

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Can be laid three times as fast as ordinary pipe, for half the labor. B. & S. type. Sand cast. Precalked Fittings also.

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Connect without threading

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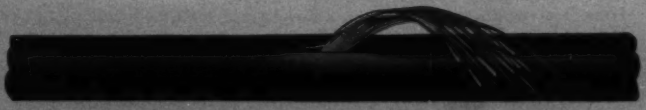
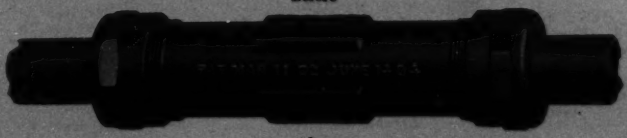


Before



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Makes Possible an Immediate Repair. Saves Both Time and Money

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WARE, MASS., U. S. A.

40 Years Old—Still Serving!

In the life of a pipe line, forty years is a long time — particularly if it is spent underground, subject within and without to corrosive onslaughts.

The pipe that can stand it is the pipe for service lines. That genuine wrought iron pipe has the necessary endurance is clearly demonstrated by service records all over the country of which the above photograph is an interesting example.

Here is a two-foot section from a line laid in 1886 by the Atchison Water Co. It is still good. It was removed simply to admit a valve. The line as a whole is in its 41st year of constant, uninterrupted service.

For sixty years, Byers has made pipe from genuine wrought iron. Its quality today is no less than that which has already defied rust for two, even three generations. Such, surely, is the ideal pipe for service lines.

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Established 1864 Pittsburgh, Pa.

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GENUINE WROUGHT IRON

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COMPLETE LINE OF WATER WORKS SUPPLIES
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FLANGED PIPE in full and short lengths
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CEMENT LINED SERVICE PIPE

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Also Curb Cocks which eliminate Iron to Brass Corrosion both inside and out.

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For Standard and High Pressure Service

Mathews Hydrants are simple in construction; hence durable, easily repaired, and maintained at low cost.

A real Frost Case makes Mathews Hydrants completely frost proof, and with an easily installed

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CAST IRON PIPE FITTINGS

"Sand-Spun" centrifugally cast pipe
Cast in refractory molds
No chill—Standard bell and beaded spigot

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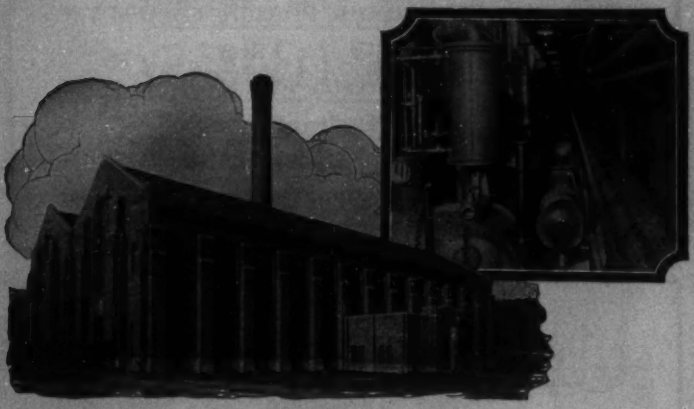

Milwaukee drinks water controlled by Kennedy Valves

THE beverage that once added to Milwaukee's fame now has been quite definitely supplanted in that city by another — as is indicated by the fact that since 1921, forty Kennedy Valves ranging in size from 24-inch up to 54-inch have been installed in various extensions of Milwaukee's water works system.

These valves are of hub and flanged end types, with and without bypass, for hand, bevel gear and electric control, and seventeen of them are of 54-inch size.

The frequency and magnitude of these extensions indicate far more than merely acceptance of prohibition — they demonstrate Milwaukee's progressiveness in steadily expanding and improving its systems of water supply, and the six repeat orders for Kennedy Valves prove the continued satisfaction obtained from each Kennedy installation.

THE KENNEDY VALVE MFG. CO.
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KENNEDY

VALVES-PIPE FITTINGS-FIRE HYDRANTS

Automatic Pressure Control Valves
Feed Water Filters
Portable Fire Hydrant Heads
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ESTABLISHED 1879

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Sluice Gates, Gate Valves and Fire Hydrants

Health and Protection First

Water delivered through dirty pipes may be a MENACE.

Incrusted water pipes mean inefficiency and loss of Fire Protection.

We Guarantee the Results of Our Method of Cleaning.

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MANUFACTURERS OF

VALVES and FIRE HYDRANTS

This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.

The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.

DOUBLE AND SINGLE GATE **VALVES,**

ALSO CHECK **VALVES,**

FOOT **VALVES.**

FIRE HYDRANTS.

YARD, WASH, AND FLUSH HYDRANTS.

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The Knuckle Joint Principle in Genuine "Rensselaer" Improved "Corey" Fire Hydrants—Means Ease of Operation

BECAUSE this principle gives great power to open or close the gate just when it is needed, and speed in movement when power is unnecessary.

The first turn of the spindle, when the gate is open, moves the valve nearly two inches, after which the speed decreases and power throughout the knuckle joint increases, until at the time of closing the valve moves scarcely one-sixteenth of an inch at each turn of the spindle, eliminating danger from water hammer when closing hydrant.

The gate is closed very tight with slight application of power to the wrench by the operator. The drip valve in the Corey Fire Hydrant prevents freezing. No accident or damage to property can occur with this hydrant by flooding the streets where runaway teams or other accident breaks off or otherwise injures the hydrant standpipe, if hydrant was properly closed at time of accident.

It will be readily seen that the hydrant gate is held in position when shut by the four arms forming braces between the back of the hydrant and the seat, consequently the hydrant barrel can be broken completely off above the ground, but the valves remain tight.

Write for copy of our Hydrant Book No. 9.

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New England Sales Manager, Lock Box 8, Northboro, Mass.

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THE CHAPMAN VALVE MANUFACTURING COMPANY

Manufacturers of

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Type of Eddy Hydrant Popularly Used

More Than Sixty Years of Experience Goes Into All

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Hydrants and Valves

BUILT TO MEET EVERY EXACTING REQUIREMENT OF WATER-WORKS SERVICE

Practical water-works men instantly recognize the superior features of Eddy products. For instance, with the hydrant.

A damaged valve can be replaced in a few minutes — Water hammer is avoided by the valve closing against the pressure and the use of the cut-off under the valve, which gradually closes it —
Stems cannot be bent in closing the hydrant.
Nothing can lodge on the valve seat to prevent closing of the valve —
The Drip Rod can be removed without interfering with the hydrant in any manner —
The position of the stem of the hydrant indicates accurately the position of the valve —
Whatever can pass the valve opening will pass the standpipe —
No frost case necessary —
All of these points are explained thoroughly in our catalogue, which will pay you to study.

The Eddy Valve, Too

Has its distinctive and individual features. The double disk gates are free to adjust themselves in different positions every time the valve is closed, thereby keeping smooth and tight faces. And two bronze hooks on the ball loosely engage with the gates to prevent them from spreading at the top. The center bearing gates are forced to their seats with equal pressure at all points. There is a good deal more worth knowing about Eddy Valves. Further details will be sent for the asking.

Other Eddy Products

The Eddy line of water-works products also includes horizontal and vertical check valves, foot valves, hydraulically operated valves, indicator posts, etc.
All goods made by the Eddy Valve Company are manufactured exclusively at Waterford, New York.

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DONALDSON IRON CO.,

MANUFACTURERS
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...AND...

Special Castings for Water and Gas.
Also Flange Pipe, Street Castings,
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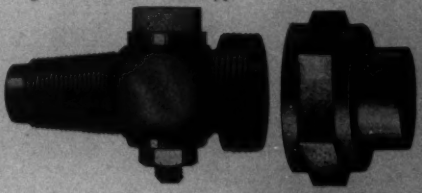
Top section is interchangeable with the "Slide Type" Buffalo Box

No change necessary in wrench or shut off keys



"CALDWELL" Water Works
Brass Goods, Curb and
Valve Boxes

None better and few as good

GEORGE A. CALDWELL CO.
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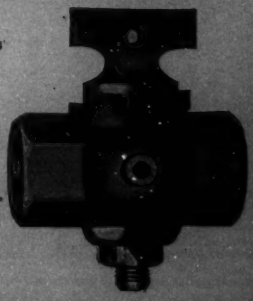

Part of 9 miles of 16" de Lavaud pipe, Class 100, recently laid in Tulsa, Oklahoma.

5% extra carrying capacity with no extra COST

Much helpful data for the engineer is contained in the U. S. Cast Iron Pipe Handbook. Write for your copy now.

SIZE for size, deLavaud pipe has a larger internal diameter than other cast iron pipe. The great strength of deLavaud pipe, the uniformity of the metal and its freedom from defects make this possible. And the extra carrying capacity of the larger diameter is further increased by the smooth interior surface of the pipe.

In the size of pipe shown above, this increase in internal diameter will result in approximately 5% greater carrying capacity . . . at no extra cost.

Whenever there is possibility of future growth in demand, the extra capacity of deLavaud pipe makes it an especially sound investment.

United States Cast Iron Pipe and Foundry Company

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Corrosion of Iron and Steel Water Pipes

Information on this subject is desired by the Committee recently appointed by the Association "to Collect and Correlate Information Concerning the Corrosion of Iron and Steel Pipes and Standpipes." Members are urged to send data relating to the characteristics of the metal, the soil, the water and the protective coatings and to the history and condition of such supply mains (not service pipes) to the undersigned for the use of the Committee.

CALEB MILLS SAVILLE, *Chairman.*
1026 Main Street, Hartford, Conn.

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CAST IRON

WATER & GAS PIPES

FLANGE PIPE

Special Castings, Fire Hydrants, Valves

General Foundry and Machine Work

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NEW YORK CITY

HIGHEST AWARD, GOLD MEDAL,
ST. LOUIS EXPOSITION, 1904

Over 100 Water Departments
use
LEAD-LINED IRON and TIN-LINED PIPES
for their service connections

MANUFACTURED BY

Lead Lined Iron Pipe Company

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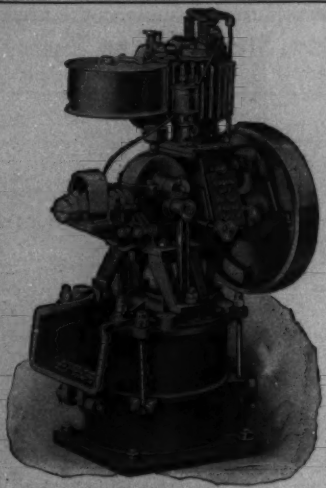

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Furnished on Hand Skid or 4-wheel Truck

"On Top" Trench Pump Unit

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PUMP SPECIALTIES

Hand and Power Outfits

Try one of our Gasoline Two-Pump
EMERGENCY UNITS

Insist on GENUINE EDSON Pumps,
Suction Hose, Diaphragm
with Bead, etc.

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LARGE STOCK ENABLES US TO MAKE QUICK SHIPMENTS

TRADE **"LEADITE"** MARK

Registered U. S. Pat. Office

Only 51 days between the decision to build an emergency water works plant - - *and the finished job!*

- - the speed with which Leadite jointing can be accomplished contributed to this remarkable feat.

THE line illustrated here is 26,000 ft. of 12" pipe with LEADITE joints.

Owing to the emergency which arose in the city for which the installation was made no trenching could be attempted.

The line lies throughout its entire length on the surface of the ground without any bracing except at the bends.

After completion the line was tested to 260 lbs. pump pressure.

It is now under constant pump working pressure of 230 lbs. For over 30 years now, LEADITE has demonstrated by test and experience that it is absolutely permanent and secure.

Leadite is self-caulking and is so simple to use that the method of using it can be taught to even the most inexperienced help in a very short time.

Added to its speed and ease of use — Leadite saves at least 75% on account of saving in material and labor.

Part of the 26,000 ft. installation, crossing an open field. Chas. E. Waddell & Co., Engineers.

Specify and use LEADITE —it saves at least 75%

Be sure it is LEADITE and accept no imitations : :

The pioneer self-caulking material for c. i. pipe. Tested and used for over 30 years.

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Agents for

The Celebrated "ULCO"

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(Every Atom Pure Lead)

For calking pipe joints under the most difficult conditions.

For overhead joints, or in wet places where the use of molten lead is not only impracticable but dangerous — **LEAD WOOL** may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe without danger of a leak.

As compared with the poured joint, in this respect, the superiority of **LEAD WOOL** is apparent.

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TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND TEN CENTS

Join Your Water Mains

WITH

LEAD-HYDRO-TITE

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AND CUT YOUR EXPENSES

50% FIRST COST

50% SMALLER BELL HOLES

75% HANDLING

100% CALKING

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That the prospective users purchase a trial lot of 1 to 5 bags, and that this be used under the direction and according to the instructions of our representative.

If, after a trial, the purchaser is not satisfied with the material, any surplus not used to be returned to the Hydraulic Development Company, and no charge to be made for any of the Hydro-Tite furnished.

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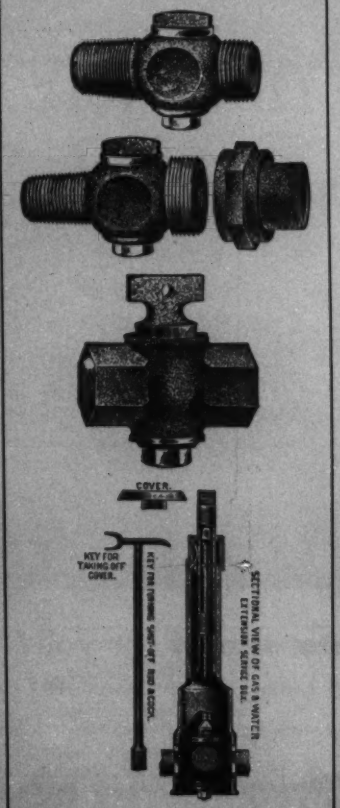

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We have them to meet every requirement

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Extension Service Boxes of proven advantages

Let us send at our risk, on 30 days' trial, a

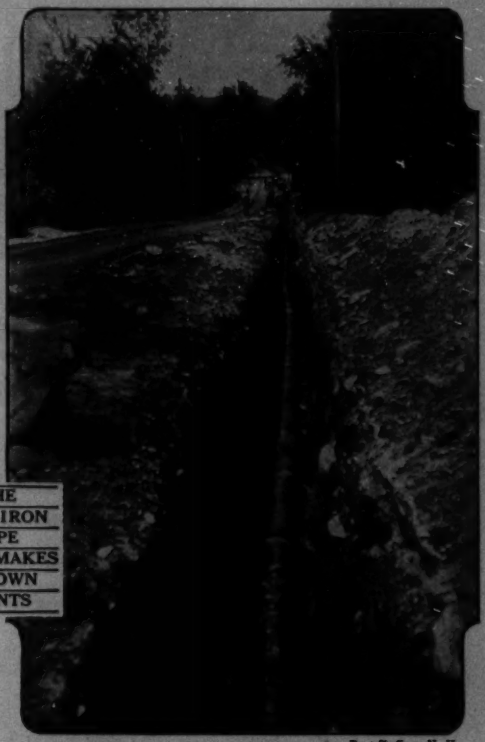
Payne's Patent Tapping Machine

which is recognized to be the most easily operated owing to the few working parts.

Hays Mfg. Co., ERIE PENNSYLVANIA

Established 1869

New!
SERVICE BOXES
With *Stay-on* Covers
Just what you have been waiting for . . . Interchangeable with "Buffalo" boxes . . . .
Ask for Monitor Service Box catalog.



THE CAST IRON PIPE THAT MAKES ITS OWN JOINTS

East Jaffrey, N. H.

Here's dependable water supply for you!

Dependable because it's 100% cast iron. No hot lead, no cold lead, no lead substitutes, no pouring, no calking. Nothing to work loose, nothing to deteriorate in these flexible, dependable joints—machined iron-to-iron *joints as tight as the wall of the pipe itself.*

Wrenches the only tools. Address nearest office.

UNIVERSAL CAST IRON PIPE
No bell holes to dig. No joints to calk.
THE CENTRAL FOUNDRY COMPANY
Subsidiary of The Universal Pipe and Radiator Company
Graybar Building, 420 Lexington Avenue
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Patent Automatic Cushioned Controlling Altitude Valves

We have enlightened many a water user in municipalities, in industrial plants and on railroads, as to the adaptability of these Golden-Anderson Valves, and as to their function of SAVING, and of eliminating troubles.

For automatically maintaining Uniform Stage of Water in Tank, Reservoir or Standpipes. Doing away with the annoyance of Freezing and Float Fixtures inside or outside of Tanks.

"Three Ways of Closing These Valves":
1st —Automatically, by water.
2nd—By Electricity, if desired.
3rd —By Hand

May also be arranged to automatically close when a break occurs in the mains. When necessary they may be so connected as to "work both ways" on a single line of pipe. No valves or fixtures inside or outside.

Sizes to 24 in.

Remember!

"HOSTS OF REFERENCES"
Valves cushioned at all times by air and water
No water hammer or bursting mains

"Made with stop starter attachment for centrifugal pumps"

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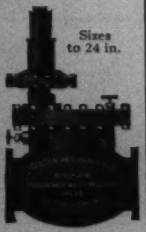
Pat. Automatic Cushioned Water Pressure Regulating Valves

1. Maintain a constant reduced pressure regardless of fluctuations on high pressure side.
2. Perfectly Cushioned by water and air. No metal-to-metal seats.
3. The best valve made for maintaining a constant low pressure where consumption is continuous.
4. Operates quickly or slowly as required — No attention necessary.
5. Positively no hammering or sticking.



Sizes to 24 in.

GOLDEN-ANDERSON
Patent Automatic Cushioned Controlling Float Valves

They carry a constant water level in feed water heaters by perfectly controlling the flow of makeup water.

Operated by protected enclosed copper float.

Cushioned by both air and water.

Operate without hammering, sticking or chattering. No metal-to-metal seats. Made angle or straightway.

Sizes 1 in. to 24 in.

GOLDEN-ANDERSON
Pat. Automatic Cushioned Water Float Valves

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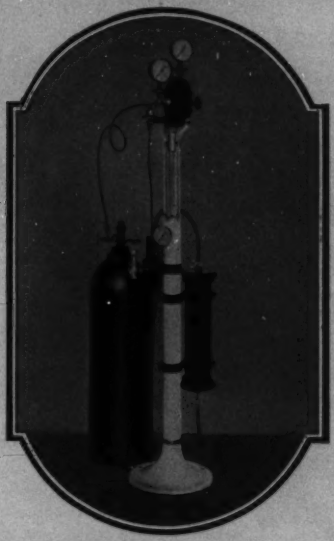

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